This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,070,141

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1898.

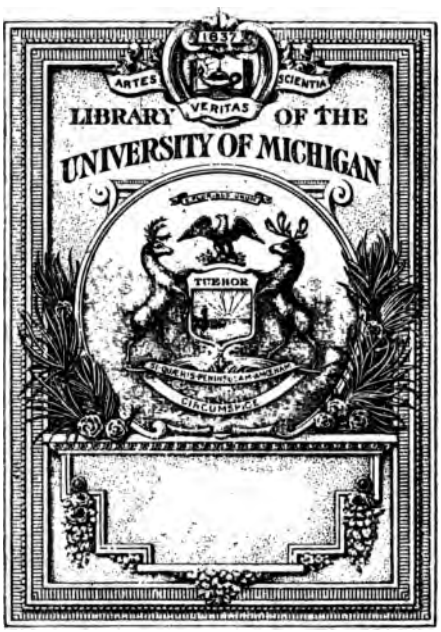
PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.,
and 32, ABINGDON STREET, WESTMINSTER, S.W.; or
JOHN MENZIES & Co., 12, HANOVER STREET, EDINBURGH, and
90, WEST NILE STREET, GLASGOW; or
HODGES, FIGGIS, & Co., LIMITED, 104, GRAFTON STREET, DUBLIN.

1899.

Price One Shilling.


1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
TUEBOR
CIRCUMSPICE

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1898.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.,
and 32, ABINGDON STREET, WESTMINSTER, S.W.; or
JOHN MENZIES & Co., 12, HANOVER STREET, EDINBURGH, and
90, WEST NILE STREET, GLASGOW; or
HODGES, FIGGIS, & Co., LIMITED, 104, GRAFTON STREET, DUBLIN.

1899.

Price One Shilling.

PREFACE.

In the *Summary of Progress* for 1897, which was the first of this series of Annual Statements, an introductory sketch was given of the origin and history of the Geological Survey and of the Museum of Practical Geology.

The present volume deals entirely with the work of the past year. It is gratifying to be able to report that both in the field and in the office and Museum much important and useful work was accomplished. Among the more noticeable portions of it, I may specially direct attention to the researches among the younger granites of the Highlands, particularly in the range of the Cairngorm Mountains and the Ben Cruachan group; to the detection of Corundum among the Cordierite-bearing rocks of the contact zone round the Ben Cruachan granite; to the finding of Arenig rocks, and the more precise definition of the position of the "Cambrian" rocks of the south-east of Ireland; to the numerous Cambrian fossils obtained in Skye; to the discovery of still further new fishes in the Upper Silurian rocks of Lanark and Ayrshire; to the ascertaining of a hitherto unsuspected Carboniferous outlier in Lorne; to the novel tectonic structures found to traverse the South Wales coal-field; to the remarkable evidence brought forward of the existence of a group of volcanoes belonging to the time of the Carboniferous Limestone in Somerset; to the new light thrown on the structure and probable extension of the North Staffordshire coal-field during the course of the revision of that district; to the additional information obtained regarding the complicated volcanic history of the western mainland of Scotland and the Inner Hebrides; and to the fresh data gathered from all parts of the three kingdoms respecting the successive stages of the Ice Age.

2046. Wt. 26682. 5000—7/99. Wy. & S. a 2

The practical applications of the work of the Geological Survey continue to be increasingly asked for both by the general public and by the various Government Departments. These enquiries however can hardly be referred to in this Report, save in general terms. They relate to water supply, building sites, mines, minerals, and many other economic or industrial questions in which a knowledge of geology is required. A brief account of them will be found in Part IV. of the present Summary.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, *Jermyn Street, London,*
17*th February*, 1899.

CONTENTS.

PAGE

PREFACE BY THE DIRECTOR-GENERAL ... iii

I FIELD-WORK ... 1

Distribution of the Staff ... 1
Pre-Cambrian ... 6
Dalradian or Younger Schists of the Scottish Highlands ... 20
Cambrian ... 53
Silurian ... 56
Old Red Sandstone ... 66
Devonian ... 94
Carboniferous (*with one illustration, p.* 107.) ... 103
Permian ... 132
Trias ... 133
Jurassic ... 138
Cretaceous ... 139
Tertiary ... 144
Pleistocene, including Glacial ... 156
Recent ... 183
New Railway-cuttings ... 187

II. PETROGRAPHICAL WORK ... 195

III. PALÆONTOLOGICAL WORK ... 201

IV. PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY ... 206

V. MAPS, SECTIONS, MEMOIRS, ETC., PUBLISHED DURING 1898 ... 207

A. Official :—
I. Maps ... 207
II. Memoirs ... 209

B. Non-Official ... 211

INDEX ... 213

PLATE I. Corundum ... *to face p.* 87

PLATE II. Sections across the Vale of Neath Disturbance ... *to face p.* 118

MAPS: Indexes to the One-inch Maps (Old Series and New Series) of England and Wales; to the General Map of England and Wales (Scale, one inch to four miles); to the One-inch Maps of Scotland and Ireland ... *At end of Volume.*

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1898.

Changes in the Staff

During the year 1898 several changes have been made in the staff of the Geological Survey in the United Kingdom. MR. C. E. DE RANCE, of the English branch of the service, resigned in March last, and the vacancy thus caused was filled up by the appointment of MR. C. B. WEDD, B.A. Another vacancy, which arose from the resignation of MR. WATTS in the autumn of 1897, was last spring filled up by the appointment of MR. WILLIAM POLLARD, M.A., D.Sc.

In the Palæontological Department some considerable changes have taken place. MR. GEORGE SHARMAN, one of the two Palæontologists and Curators of the Fossil Collections, retired on 31st December, 1897. His colleague, MR. E. T. NEWTON, F.R.S., was thereupon promoted to have entire charge of the Palæontological Department, with the same rate of salary as that of a District Surveyor. Two offices were created of Assistant-Palæontologist and Assistant-Curator of Fossils. To the former, MR. F. L. KITCHIN, M.A., Ph.D., was appointed, and he entered on its duties on 12th March last. To the latter MR. H. A. ALLEN was advanced, with increase of salary. The position of the Fossil Collector, MR. J. RHODES, was likewise improved by the allocation to him of the duties of Assistant in the Fossil Department, whilst he still performs the duties of Fossil Collector.

On the Irish staff, the vacancy caused by the retirement of PROFESSOR SOLLAS in 1897 was filled in April last by the appointment of MR. HENRY J. SEYMOUR, B.A., who will conduct the petrographical work of that branch of the Survey.

I.—FIELD WORK.

Distribution of the staff in the field.

The mapping during the past year has been continued in each of the three kingdoms in the several districts described in the last Summary of Progress. Its general distribution will here be briefly stated, and its detailed results will be more fully given in subsequent pages (p. 6, *et seq.*).

ENGLAND AND WALES.—In this part of the United Kingdom the energies of the service are mainly concentrated

on the revision of the counties upon the maps on a scale of six inches to a mile. Two important kinds of revision are undertaken. In one of these the superficial deposits are traced out with especial care, so as to lay a foundation for a general agricultural or subsoil map of the whole country. In the other, the various mineral districts, originally surveyed on the one-inch maps (which were the only Ordnance sheets then available), are now being mapped out on the larger scale and brought up to date. In both these revisions every effort is used to make the maps as complete and accurate as possible, and to bring them abreast of our present knowledge. Thus the revised maps of the superficial deposits include also all corrections and additions which the progress of time has shown to be necessary in the mapping of the older formations underneath, while the re-survey of the mineral fields has involved at the same time the detailed mapping of the superficial deposits of these districts.

eicester-ire and S. erbyshire.

The re-examination of the coal-field and surrounding country in Leicestershire and southern Derbyshire has been continued by MR. FOX-STRANGWAYS, who has surveyed 71¾ square miles of that region, and has traced 426 miles of geological boundary-lines, of which 256 related to the superficial deposits or Drift.

orth affordshire.

The North Staffordshire coal-field and the region around it have engaged the services of five members of the staff. MR. DE RANCE'S retirement made it desirable that the revision of this ground should not fall behind, but be pushed forward with all possible vigour. Accordingly MR. GIBSON, who has had considerable experience in coal-field work, was temporarily transferred from South Wales to carry on the colliery part of the revision. MR. WEDD on his appointment was stationed, under MR. GIBSON'S supervision, on the red rocks and Drifts along the western border of the coal-field. On completing his working season among the Grampian Mountains, MR. BARROW was moved in the early autumn into the tract of Lower Carboniferous rocks lying to the east of the coal-field, while in like manner MR. LAMPLUGH was transferred to the ground along its southern border. MR. FOX-STRANGWAYS was placed in general charge of the revision, and from his station at Leicester was able from time to time to inspect the progress of the work. The total area in North Staffordshire thus surveyed amounts to 180½ square miles, and the boundary-lines to 760 miles, whereof 452 represent the distribution of the various drifts.

The southern counties are now undergoing revision on the large scale of map. The general charge of this work is in the hands of MR. H. B. WOODWARD, F.R.S., District Surveyor. In this region it has been found desirable to accelerate the re-mapping of the superficial geology of the London District, and for that purpose to intermit for the present the prosecution of the revision of Northamptonshire so as to permit of the

asin of the hames.

transference of MR. CAMERON from that county to the basin of the Thames. The original geological survey of Middlesex and the surrounding region, made upon the one-inch scale Ordnance maps, did not discriminate various superficial

deposits which subsequent experience has shown it to be of practical importance to represent separately upon large-scale maps. Thus the brick-earth and gravel were formerly grouped together, whereas it is most desirable that these valley-drifts should be carefully distinguished. For many practical purposes, such as water-supply, drainage, choice of building-sites, market-gardens, etc., the necessity for minute and accurate mapping of the superficial accumulations is now everywhere recognised. When the survey of the district is completed, it is intended to prepare and issue a colour-printed edition of the map. From the large sale of the Survey memoir on "Soils and Subsoils," it may be expected that a detailed subsoil map of the London district will be found to be of considerable general utility.

Northamptonshire.

In Northamptonshire, before his transference to the Thames Valley, Mr. Cameron had last year completed the revision of an area of 20 square miles, and had traced 135 miles of boundary-lines, including 75 that related to Drift. Since he began work in Middlesex he has mapped a further area of 32 square miles and 86 miles of Drift boundaries.

Oxfordshire, Berkshire, and Buckinghamshire.

In Oxfordshire, Berkshire and Buckinghamshire Mr. J. H. Blake, from his central station at Oxford, has surveyed a total area of 51 square miles, which have comprised the tracing of 161 miles of boundary lines, 84 of these being Drift lines.

Dorsetshire, Hampshire and Wiltshire.

In Dorsetshire, Hampshire and Wiltshire the revision has been in the hands of Mr. Reid, Mr. Bennett and Mr. Hinxman. In the Southampton district Mr. Reid has surveyed 68 square miles, and has thus been able to fill in considerable tracts that had not been completed by Mr. Whitaker at the time of his retirement. This mapping has necessitated the tracing of 267 miles of boundary-lines, of which 179 belonged to the superficial deposits. From his station at Salisbury Mr. Bennett completed an area of about 50 square miles and mapped 165 miles of boundary-lines, including 56 miles of Drift-boundaries. Mr. Hinxman, temporarily transferred from the Scottish staff, was stationed in October in the western part of Dorsetshire, where, in the district around Maiden Newton, he revised 20 square miles and traced 74 miles of boundary, whereof 47 related to the Drift. In Hampshire Mr. Hawkins spent a short time in completing a small area of 6¼ square miles, where he traced 19 miles of boundary, six of which were Drift-lines.

Devon and Cornwall.

In Devon and Cornwall three surveyors have been engaged. From Plymouth as a centre, Mr. Ussher has continued his re-mapping of the borders of the two counties, where he has surveyed 29 square miles, tracing 133 miles of boundaries, including 88 miles of Drift-lines. From Falmouth Mr. J. B. Hill surveyed an area of 24 square miles, including 49 miles of boundary. This return would have been considerably larger had he not been disabled from field-work by continued ill-health for much of the year. Mr. Wilkinson moved in October from Argyllshire to Cornwall, and from his station at Penzance, during a few weeks of field-work, mapped six square miles, with three miles of boundary-lines.

outh Wales coal-field.

The revision of the South Wales coal-field has continued to make satisfactory progress. Under MR. A. STRAHAN'S supervision the field-work has been carried on by MR. R. H. TIDDEMAN, MR. W. GIBSON, and MR. T. C. CANTRILL. The total area surveyed in this region by these four officers has been 131½ square miles, comprising 799 miles of boundary, of which 303 relate to the Drift. It should be added that this return was necessarily reduced by the transference of MR. GIBSON to North Staffordshire as already mentioned. He was absent from South Wales until late in the autumn.

The total area revised in England and Wales during the past year has been 690 square miles. The extent of boundary-lines traced has amounted to 3,077 miles, and of these rather more than half, or 1,634, have been connected with the mapping of the superficial deposits. Taking the country as a whole, each square mile of ground surveyed has involved the tracing of about four and a half miles of geological boundaries.

SCOTLAND.—The field-work has been continued in the districts referred to in the last *Summary of Progress*. MESSRS. PEACH, HORNE, and POCOCK were engaged during most of the season in the mountainous ground around Lochs Fannich and Luichart. MR. PEACH mapped an area of 61 square miles within the combined county of Ross and Cromarty, and traced 549 miles of boundary-lines. He was able to connect the surveyed area on the west side of the country with that already mapped on the east side. Thus a continuous tract of surveyed ground now stretches completely across the Northern Highlands from Skye to the Moray Firth. Besides this mapping, MR. PEACH was engaged with MR. HORNE and MR. A. MACCONOCHIE in studying sections of the Silurian rocks in the Pentland Hills, Lanarkshire, and Moffatdale, in order to procure additional material for the completion of the monograph on the Silurian Rocks of the Southern Uplands, to which more special reference will be made in a subsequent page.

ross and omarty.

In the Fannich Forest, and subsequently in Eastern Ross and around Kiltarlity, MR. HORNE mapped a total area of 50 square miles, and 189½ miles of geological boundary. Later in the year he revisited parts of the counties of Banff and Aberdeen for the purpose of procuring fresh information in reference to a map about to be engraved, and traced there 17½ additional miles of boundary.

After the close of the possible working season among the Ross-shire mountains, MR. POCOCK was transferred to Argyllshire to assist in completing some of the work left unfinished by MR. HILL. In the autumn he returned to the Caithness ground, on which he was engaged during the preceding year. His total area of field-work amounts to 52¾ square miles, with 319 miles of boundaries.

enelg.

MR. CLOUGH resumed his station at Glenelg, but immediately thereafter he met with a serious accident in the course of his field-work. Slipping on a steep slope, he so injured his foot as to be unable to put it to the ground, and he was consequently

incapacitated from field-work during the whole of the rest of the year. The progress of the mapping of the North-West Highlands has thus been materially checked by his unfortunate disablement.

Aberdeenshire.

In Aberdeenshire, MR. BARROW resumed his work in the Braemar district, where he surveyed a tract of 28 square miles, with 148 miles of boundary; while in the same region 44⅝ square miles were mapped by MR. CUNNINGHAM-CRAIG, including 250½ miles of geological lines. MR. BARROW did not return to his Braemar ground after the summer, but took part in the revision of North Staffordshire, as already stated.

Badenoch.

Further to the west, in the district of Badenoch and the Monadhliath Mountains, field-work was resumed by MR. HINXMAN, who surveyed there 41¼ square miles, with 217¾ miles of boundary. Later in the season he completed a tract of 11 square miles, with 34¾ miles of boundary, in the low grounds around Beauly, before he moved southward to take part in the revision of Dorsetshire, to which reference has already been made.

Argyllshire.

In Argyllshire six surveyors have been at work during the past year. In the Loch Awe district MR. HILL, during his return to the district for convalescence, continued his former work, completing 15 square miles, and tracing 128 miles of boundary. Further to the north and north-west, around Ben Cruachan and in the region of Glen Etive, MR. KYNASTON has mapped 50½ square miles with 235 miles of boundaries. In the Oban district 40⅛ square miles have been mapped by MR. SYMES, with 162 miles of boundary. In the country on either side of Loch Eil, MR. GRANT-WILSON'S area of survey last year amounts to 54 square miles, and includes 201 miles of geological lines. In Jura MR. WILKINSON was able to add to his area already surveyed 52 square miles, including 274 miles of boundary-lines.

Arran.

In Arran MR. GUNN surveyed 50 square miles and traced 296 miles of boundaries.

Perthshire.

In Perthshire, around Strathyre and the Trossachs, MR. CUNNINGHAM-CRAIG resumed during part of the year the ground on which he had previously been at work, and completed an area of 26⅝ square miles with 216½ miles of boundary.

Isle of Sky

In the island of Skye MR. HARKER, in continuing the survey of the Cuillin Hills and adjoining tracts, mapped an area of 33¼ square miles and traced 647½ miles of boundary-lines. The structure of this ground has been found to be still more complicated than that reported in the last *Summary of Progress*, for it has involved the following out of 19½ miles of geological boundaries in each square mile of area.

The total area surveyed in Scotland during 1898 has been 610⅛ square miles, and the total aggregate length of boundary-lines run has been 3,868½ miles. Every square mile mapped has thus on the average required the tracing of rather more than six miles of geological lines.

IRELAND.—The field-work in this part of the British Isles consists in the revision of the published maps for the purpose of taking

advantage of all the fresh evidence which has appeared during the long lapse of time since many of them were issued, and of bringing them abreast of the present state of geological science. This revision has been begun with the older formations, which are being re-examined all over the east and south of the island. The Silurian tracts are now not far from completed. Last year the districts over which the work extended comprised the counties of Wicklow and Wexford, where MESSRS. EGAN and MCHENRY were engaged, and of Tipperary, Limerick, Cork, Kilkenny, and Waterford, in which MR. KILROE was employed. The fossil-collector, MR. R. CLARK, generally preceded these officers on the ground, so as to supply them with palæontological data for separating the different Silurian formations, and especially for distinguishing the tracts of Lower from those of Upper Silurian rocks. A number of new fossil localities have thus been discovered. The total number of fossils collected during the year was 466.

The appointment of MR. HENRY J. SEYMOUR to fill the vacancy left by the resignation of PROFESSOR SOLLAS, has allowed the petrographical work of the service to be resumed at the Dublin office. MR. SEYMOUR has had nearly 200 fresh slides of Irish rocks prepared, and has supplied reports for the guidance of the field-work in regard to the nomenclature of the igneous rocks in the areas now undergoing revision.

Such being the general distribution of the field-work over the British Isles during the past year, some detailed account will now be given of the more important or interesting results of this work. For convenience of narrative the stratigraphical order of formations will be followed, beginning with the oldest.

PRE-CAMBRIAN.

Ross-shire.

The whole of the undisplaced pre-Cambrian rocks of the mainland having now been surveyed, the field-work of the staff was continued last year eastward, across the mountainous ground of western Inverness, Ross-shire, Sutherland, and Caithness. As already explained, the mapping of the Glenelg district has been unfortunately interrupted by the serious accident to MR. CLOUGH. To the east of that ground the work was resumed in the region of Lochs Fannich, Luichart, and Garve, by MESSRS. PEACH, HORNE and POCOCK.

MR. PEACH submits the following statement of the ground mapped by him during the year, in sheets 82, 83, 92, and 93 of the map of Scotland, embracing a tract of about 50 square miles, between Achnasheen and Garve in Ross-shire.

The schistose rocks form a continuation of those already mapped further towards the south-west, and are naturally divisible into two groups. Of these the lower and presumably the older (*a*) consists of hornblendic gneisses, which form the crests

of folds and an overlying series (*b*) of granulitic muscovite-biotite schists and gneisses, of what is now known as "Moine" type. Loch Luichart district. (Mr. B. N. Peach.)

(*a*) The hornblendic gneisses may be regarded as probably uplifts of the Lewisian series. They are met with in two separate areas of the district surveyed. One of these is an eastward extension of a mass of the same rock which was mapped in 1895 and was referred to in the *Geological Survey Report* for that year (p. 19). Allusion was made in that *Report* to the large size of some of the slices of the Lewisian gneiss which had been thrust forward among the Moine-schists, and this particular mass was spoken of as perhaps covering more than fifty square miles. Its dimensions, however, will prove to be vastly greater than was at that time supposed, for it has been followed for many miles further east without reaching its termination in that direction, and it evidently stretches southward far beyond the limits within which it has been mapped. The portion of the map surveyed last year forms a narrow strip which sweeps in a sickle-like form round the northern flanks of Sgurr a Mhullin (2,778 feet) south of Achanalt, and passes southwards into ground not yet examined near the head of Allt a Mhullin. Its position on the mountain is indicated by the smooth feature (so well seen from the railway) from which the fine cliffs and peaks of the Sgurr abruptly rise. The rocks which enter into its composition are chiefly granulitic hornblende-biotite-gneisses. Granulitic quartz-felspar-biotite-gneisses occur in small quantity; hornblende-schist and epidiorite much more abundantly, while ultrabasic rocks are also present which appear to have been peridotites, though now for the most part in the condition of unctuous schists with clear colourless amphibole. Epidote is a common mineral in most of the masses. The general assemblage of these rocks, together with their mode of occurrence, at once recalls the Lewisian gneiss as developed at Loch Alsh, Glenelg, Sheildaig, and many other parts of the West Coast.

The second mass lies to the south of the upper end of Loch Luichart, and shows on the map like a fork, the apex of which rests on Loch Bhad Ghaineamhaich, about three miles south of Loch Luichart Station, while the prongs reach the shores of Loch Luichart at a distance from each other of about two miles. In addition to the types of rock already mentioned, this mass includes a white and pink crystalline marble with calc-silicates, much like the limestone of Glenelg, the outcrop of which follows the fold that makes the northern prong of the fork. As in the case of the larger mass of gneiss, the course of this less extensive slice is made evident from the railway by the smooth green pasture-covered slope to which the calcareous and decomposing granulitic hornblendic rocks give rise, and which offers so marked a contrast to the sombre vegetation and grey crags of the surrounding "Moine-schist" and muscovite-biotite-gneiss.

(*b*) The "Moine-schist" and muscovite-biotite schist or gneiss of the overlying, and therefore presumably newer, series occupy by far the greater part of the area. They may be looked on as

the "rocks of the country." With the exception of a few foliated igneous intrusions and quartzo-felspathic veins, they consist essentially of granulitic muscovite-biotite-gneisses, varying from quartzo-micaceous flagstones or "Moine-schists," on the one side, through every intermediate grade into rocks made up of felted muscovite and biotite with included streaks, lenticles, and knots of quartz and quartzo-felspathic intergrowths of all sizes, from mere grains and films up to masses over a couple of feet across and yards in length. All these varieties are in places more or less garnetiferous, but the garnets are largest and most numerous in the more micaceous rocks and their quartzo-felspathic accompaniments. For convenience of description the more quartzose rocks will here be spoken of as "Moine-schist" or "Moine-gneiss," and the more micaceous rocks as "Muscovite-biotite-gneiss." These two types of rock have been distinguished on the map by lines and colours. The origin of the "Moine-schists" has been a problem that has constantly engaged the attention of the Survey since the rocks were first mapped in the West of Sutherland. During the last few years the conviction has been steadily gaining ground that much of these schists originally consisted of sedimentary strata. In the district surveyed last year by MR. PEACH the schists and gneisses of the "Moine" type may be supposed to have been originally sandstones or arkoses; the muscovite-biotite-gneiss was in all probability an argillaceous rock, while the intermediate types may represent varying admixtures of these two kinds of sediment.

That these rocks were originally clastic is rendered almost certain by their colour-banding and the distinct traces of current-bedding which they still present. In this area, although the rocks have been intensely plicated, they have not been much affected by cleavage or foliation. In most cases the new micas have been developed chiefly along what appear to have been the bedding-planes. The original quartz and felspar grains have been almost entirely granulitized, and perhaps the only materials that have been left in the condition in which they were deposited are a few refractory minerals, such as rutile and zircon, with possibly the cores of some of the alkaline felspar-grains that have escaped the granulitization which has affected their outer parts. Some layers of schist appear to have been of more complex chemical composition than others, for on the west side of Loch Luichart, close to the farmhouse of Arrieleitrach, thin bands of mica-schist occur in which tourmaline is extremely abundant. Zoisite also occurs in thin beds in the Moine-schist, and as knots and lenticles in the Muscovite-biotite gneiss.

There seems to be a definite order in at least the local succession of these rocks. In that part of the district which lies east of a line drawn S.S.W. from the head of Loch Luichart, and which coincides with a line of fault to be mentioned in the sequel, Moine-schists always lie next to the older gneisses, while the centres of the synclines of these schists are occupied by the muscovite-biotite-gneiss which is here, therefore, the highest

rock of the series. A similar arrangement is met with in the part of the area to the west of the fault, but it is not quite certain that other Moine-schists may not there in turn overlie the muscovite-biotite-gneiss. In both tracts the junction between the Moine-schists and the older gneisses wherever seen is quite sharp, and while the character of the overlying rock remains constant, that of the lower series varies from one exposure to another—a relation which suggests the inference that the junction between the two rock-groups is an unconformable one. Moreover the disposition of the Moine-schist with regard to the old gneiss core on Sgurr Mhullin strongly points to an overlap of different layers of the younger rocks upon the older, and further serves to indicate that all the exposures of the older gneiss in the present area may represent the tops of ridges which still remained uncovered after a considerable part of the sediment that now forms the Moine-schist had been deposited. Loch Luichart district. (Mr. B. N. Peach.)

Foliated Igneous Rocks—Augen-gneiss.—Several types of foliated igneous rocks occur associated with the Moine-schist and Muscovite-biotite-gneiss. On the north shore of Loch Luichart, within half-a-mile of the mouth of Corriemoillie Burn and in the adjacent railway cuttings, four outcrops appear of a fine augen-gneiss or granite, like the well-known "Inchbae" rock, of which these outcrops may possibly be the southern extension. The rock shows fine Carlsbad twin-crystals of a pink-coloured felspar (orthoclase) oriented in a definite direction and enclosed among winding wisps and streaks of a granulitic ground-mass composed of quartz, felspar, and micas, together with small crystals of garnet and sphene. The rock occurs as a sill or sills intruded more or less between the bedding planes of the Moine-schist, and shows fine-grained or "chilled" edges, where its texture is much finer and evener than in the centre, and where the porphyritic crystals seem to be absent. This fine-grained marginal material is always more or less foliated. In most places its foliation-planes have not been observed to run parallel to the cooling surfaces, but rather to cut them at a considerable angle, and to be apparently continuous with those of the adjacent Moine-schists. This augen-gneiss would thus seem to have been intruded into the original sediments before they were converted into their present condition of Moine-schists, and it may be inferred that both rocks had their present structures impressed upon them at one and the same time. There are even grounds for the belief that the four outcrops of augen-gneiss are portions of one single sill brought up to the surface by successive folds, which in that case must be isoclinal, as all the outcrops dip towards the south-east. Though such a structure cannot be demonstrated on the ground, owing to the covering of drift under which the rocks are hidden, yet on both shores of Loch Luichart, a little further south, the schists can be clearly seen in cliff-sections to have been thrown into innumerable folds of this type, wherein both limbs dip in the same direction. In fact this arrangement has constantly to be borne in mind, as it really affords the key to the structure of the whole area.

ch
uichart
strict.
[r. B. N.
ach:)

Within a belt of ground about a mile wide, lying to the west of a line of fault which extends from the west end of Loch Luichart southwards to the bend of the River Meig at Milton of Strath Conon, dykes of fine-grained foliated granite occur. They may be studied where exposed in rock-surfaces near the bridge across the Conon south of Loch Luichart Station. As small dykes, sills, and veins, they traverse the Moine-schist in all directions. They are all granulitic and foliated parallel with the foliation of the surrounding schist, irrespective of the trend of the individual dykes.

Sills of epidiorite or massive amphibolite and hornblende-schist are found chiefly to the east of the fault already mentioned and south of a line drawn from a point about a mile and a half south of Loch Luichart Station eastward to Killin Farm, near the head of Loch Garve. They appear to have been intruded into two horizons in the newer gneiss, and to cling to them with great persistency. The lower of these horizons lies near the top of the Moine-schist, and its invading sill, now consisting of hornblende-schist, is usually larger, more continuous, and more even in thickness than that which occupies the higher horizon. The upper sill has taken its place within the muscovite-biotite-gneiss and near the base of that group. It often appears as a series of nodes or lenticles of coarse garnetiferous epidiorite or amphibolite strung together by a thin layer of garnetiferous hornblende-biotite-schist, while at other times the lenticles are quite detached from one another though still disposed in lines so as to give the impression that they are portions of a once continuous layer which has been wrenched into fragments. The manner in which the muscovite-biotite-gneiss is puckered, involved, and filled with lenticles of quartz and felspar further deepens this impression. The micaceous bands seem to have given way to pressure and torsion to a greater degree than the more rigid Moine-schist.

Structure of the Ground.—Throughout the whole area all the rocks here mentioned have been thrown into a series of folds, which for the most part are isoclinal. While the long axes of these folds vary constantly in direction, and at some part or other of the area are directed to all points of the compass, their main trend is E.N.E. and W.S.W., while the dip of each limb is usually towards the South and East. By this structure the strata have been indefinitely repeated. The order of succession of the newer gneisses having now been well established in the course of the mapping, and the hornblende-schist sills having been ascertained to occupy certain definite horizons, the great folds of the rocks have been determined, and traced upon the maps over the greater portion of the area surveyed last season.

Along the course of the fault which extends across the district southwards from the head of Loch Luichart, the outcrops of the different schists and the axes of the folds seem to have been dragged round for some distance on both sides till they almost coincide with the line of fault, as if the dislocation

had been the result of some great lateral wrench rather than that of an ordinary fault. In this case there is some ground for the belief that both lateral and vertical movements have taken place. The old gneiss core of Sgurr a Mhullin has probably been brought to the surface by the same set of folds as those of the hills south of Loch Luichart, and in that case the displacement would show the amount of lateral wrench. As possible evidence of the vertical movement, it may be mentioned that the rocks on the west side of the fault are everywhere in a higher state of crystallisation than those on the east side, and are also much more filled with igneous intrusions, which had evidently been injected prior to the faulting. This more mineralised side is therefore in all probability the side of upthrow. The course of the fault is marked by a great deal of brecciated rock, which is generally stained deep red by hæmatite, as if the schists had once been covered by a red formation which has since been wholly removed. That such a covering did really once overspread this ground is highly probable, for an outlier of Old Red Sandstone occurs just east of the line of fault on Ben Bhreac, about two miles north of Loch Luichart Lodge, just outside of the district here described.

Loch Luichart district. (Mr. B. N. Peach.)

A few dykes of mica-trap, later in date than the production of the schistosity of the region, have been met with. One of these, about 8 feet broad, has been traced in the schists on An Cabar to the south of Loch Fannich. Another thin vein with large hexagonal plates of biotite crosses the River Bran about 3 miles east of Achnasheen, and a narrow dyke of lamprophyre occurs on the high ground between Loch Luichart and the head of Loch Garve. At Creag a Chaorinn a dyke of mica-trap may be seen to penetrate from the schist into the conglomerate, whence the conclusion may be drawn that the date of intrusion of some of these rocks must be later than at least some part of the Old Red Sandstone of the Cromarty Firth basin.

Fannich Forest. (Mr. Horne

The area surveyed by MR. HORNE in this part of Ross-shire lay between Loch Fannich and the watershed of the range of the Fannich Mountains. He has been able to join up his work with that carried by MR. GUNN southwards from Loch Broom to the same watershed, which was described in the *Summary of Progress* for 1897 (p. 38). The same groups of rock traced by the latter geologist have now been followed into the area surveyed by MR. PEACH, and the general sequence of rock-groups in the region has been established. These groups, as given by MR. GUNN, are here cited in what appears to be a descending order:—

1. Acid gneiss, granulitic and granitoid, with basic lenticles, knots and bands of hornblende-schist, epidiorite and garnet-hornblende-rock; resembling certain types of the Lewisian gneiss.

2. Massive biotite-gneiss, highly garnetiferous, with irregular masses of dark garnet-hornblende-rock. (Meall Dubh and Meall an't Sithe gneiss.)

3. Granulitic quartzose schist or gneiss; flaggy, fine-grained, light-grey, weathering white; quartz-biotite-granulite or Moine-schist. (Meall-a' Chrasgaidh rock.)

Fannich Forest. (Mr. Horne.)

4. Biotite-schist, dark grey to black, with small garnets in certain bands. It includes a prominent zone of granulitic grey quartzose schist. (Sgurr Mor.)

5. A thick group of massive and flaggy granulitic quartzose schists (quartz-biotite-granulites), with thin bands and partings of dark biotite-schist.

The relations of the first four of these groups are well displayed in the great corrie (Allt Choire Mhoir) which separates the two highest peaks of the Fannich chain—Sgurr Mor, 3,637 feet, and Sgurr nan Clach Geala, 3,581 feet—and likewise on the slopes of these mountains. The members of each group in succession rise to the surface, with an apparent persistent dip to the west or west-south-west. No. 1 is met with on the south-west slope of Sgurr nan Clach Geala, and No. 4 on the lofty ground round Sgurr Mor, about a mile further east. These groups of rock form more or less parallel belts, which, by means of the sections laid bare in Allt Choire Mhoir, Allt Choire Bhig, and other adjacent exposures, can be traced southwards to Loch Fannich. It is noteworthy, however, that as the respective groups are followed southwards to the mouth of Allt Choire Mhoir, west of Fannich Lodge, the westerly dips, so persistent on the watershed, give place to highly inclined dips to the east.

On the south-west slope of Sgurr nan Clach Geala the acid gneiss (No. 1), which there consists of granulitic biotite-gneiss with flaser-structure, rests on the garnetiferous biotite-gneiss (No. 2); both rocks dipping to the west at angles that vary from 20° to 35°. Southwards along the crest of the ridge from Sgurr nan Clach Geala, tongues of the garnetiferous biotite-gneiss are seen to be infolded in the acid gneiss (No. 1), and where this relationship appears the prevalent dip is no longer to the west but to the east, from 30° to 50°. Thin sills of hornblende-schist occur in the acid gneiss near its junction with the massive biotite-gneiss (No. 2). Indeed near the source of Allt Leac a' Bhealaich, that drains the south-west slope of Sgurr nan Clach Geala, bands of epidiorite and garnet-hornblende rock are associated with biotite gneisses in such a way as to recall certain types of Lewisian gneiss. Similar rocks forming part of No. 1 are met with on the hills north-east of Cabuie, in Abhuinn Nid, and on the slopes of A Chailleach (3,276 feet), the most westerly peak of the Fannich group. Thin pegmatites from one to two feet thick with small prisms of tourmaline have been detected in Allt Leac a Bhealaich north of Cabuie.

Along the crag that runs southwards from Sgurr nan Clach Geala, on the west side of Allt Choire Mhoir, the coarse garnetiferous biotite-gneiss (No. 2) forms a prominent belt from a quarter to half a mile in width. The characteristic features of this rock are, the abundance of its garnets, and the presence in it of quartzo-felspathic constituents in strings and knots. Sometimes the quartzo-felspathic materials are arranged with the biotite in parallel folia, thus forming a coarsely banded gneiss; sometimes they disappear and the rock merges into a flaky biotite-schist. In places muscovite is largely developed

and the rock becomes a garnetiferous muscovite-biotite-schist or gneiss. Fannich Forest. (Mr. Horne.

The grey flaggy quartzose schists (No. 3), well seen on the east slope of Sgurr nan Clach Geala, are inclined to the west at angles of 40°–60°. From that point southwards they can be traced as a narrow belt about a quarter of a mile broad to Allt Choire Mhoir, where they become vertical, and eventually dip to the east and east-north-east at about 70°.

The members of the succeeding group (No. 4), consisting mainly of biotite-schists, are displayed on the col at the head of Allt Choire Mhoir, on Sgurr Mor, and on the ridge that separates Allt Choire Mhoir from Allt Choire Bhig. The prominent band of quartz-schist (quartz-biotite-granulite), about 200 feet thick, has been traced from the corrie on the east side of Sgurr Mhoir, across the watershed, to near the foot of Allt Choire Bhig. Although this mica-schist group is highly puckered, the sections on the cliffs round Sgurr Mor show that the rocks are inclined to the west, while about three miles to the south they are either vertical or highly inclined to the east or west. The bands of zoisite-rock, detected by MR. GUNN in this group, on the north side of the Fannich Mountains, have been observed at various localities between Sgurr Mor and Loch Fannich. They occur in the biotite-schist, in seams from one to three inches thick, which, on weathered surfaces, show prisms of zoisite about a quarter of an inch in length. Sometimes, where the schists are highly puckered, the zoisite rocks appear as small lenticles. Thin slides, prepared from specimens collected by MR. HORNE in this region, have been examined under the microscope by MR. TEALL, who has furnished the following description of them:—

[8,203.] West slope of Sgurr Mor Fannich. Light grey, fine-grained granulite with conspicuous prisms of zoisite about ¼ inch in length on the flat surface of the specimen. Under the microscope appear garnet (colourless in thin section), zoisite and quartz, with biotite, chlorite and sphene as accessories. Undoubtedly allied to MR. GUNN'S rock, but without the hornblende; quartz-garnet-zoisite-granulite or, in short, zoisite-granulite.

[8,205. Same locality. Similar to the above but darker and containing larger garnets. Under the microscope are seen garnet, zoisite, quartz, plagioclase, hornblende and biotite. Opaque particles as in 8,204. The minerals are not uniformly distributed. The hornblende is usually in association with the felspar, and the zoisite with the quartz and garnet. The rock is more or less banded; garnet-zoisite-amphibolite.

The eastern portion of the Fannich range is composed of massive and flaggy quartzose schists with thin intercalations and partings of biotite schist (No. 5). These quartz-biotite-granulites present the normal characters of the "Moine-schists" throughout the counties of Sutherland and Ross. Along their line of junction with No. 4—the Sgurr Mor biotite-schists to the west— there is evidence of sharp plication and inversion. In the section in Allt Choire Bhig the rocks of the two groups are vertical, while on the lofty crags of the col between Sgurr Mor and Meallan Rairigidh the quartzose granulites (No. 5) have been made to overlie the biotite-schists (No. 4). The system of Z-shaped

'annich 'orest. Mr. Horne.)

folding characteristic of this inversion is well seen on the cliff at the head of Allt Choire Bhig.

Along the eastern part of the Fannich range from Meallan Rairigidh by An Coileachan to the mouth of Loch Fannich the members of group 5 are arranged in a great synclinal fold, with the axis of which the crest of the range more or less coincides, in a south-east-by-south direction. On both limbs of the fold the rocks dip at gentle angles of 12°–20°, till in the eastern limb of the chain they become vertical or highly inclined to the west. The latter area, north of the mouth of Loch Fannich, has been mapped by MR. POCOCK, and will be referred to a little further on.

An interesting feature in the structure of the eastern part of the Fannich range is the occurrence of three outliers of biotite-schist, (1) on the crest of Meallan Rairigidh (3,109 ft.), (2) on An Coileachan, (3) on a hill about a half a mile to the north of the mouth of Loch Fannich. These may be outlying patches of No. 4 which have been isolated by denudation. They form thin cakes composed of flaky and granulitic biotite-schist resting on the gently inclined quartz-granulites (No. 5). The occurrence of bands rich in zoisite in the first and third of these outliers lends some support to this correlation.

No sills or bands of hornblende-schist have as yet been detected in the thick group of siliceous schists or gneiss (No. 5) in the eastern part of the Fannich range. Pegmatites are of rare occurrence. Thin veins of microcline-pegmatite have been observed in the granulitic biotite-schists of Meallan Rairigidh and a similar rock has been noted in No. 5 in Corrie Riabhach. With reference to the latter MR. TEALL states that "it is not intended to imply that soda-felspars are absent from these pegmatites, but only that microcline is present. They are not purely albite-pegmatites, such as occur in segregations in the Cowal district and in South Devon."

The survey of the western portion of the Fannich range was not completed before the beginning of the deer-stalking season, when mapping in forest ground is suspended, but sufficient evidence was obtained to prove that groups 2 and 3 appear on the western limb of the fold, to the west of A Chailleach, where the rocks of these groups dip to the east under the acid gneiss (No. 1). In other words, Nos. 2 and 3 can be traced continuously from the west slope of A Chailleach, where they have an easterly dip, round the northern limit of the syncline, thence to Sgurr nan Clach Geala, where, as already indicated, they rise to the surface with a westerly dip.

Two hypotheses may be advanced to explain these geological relationships, where the acid gneiss with basic masses seems to rest on the underlying groups 2 and 3. (1) The structure may be analogous to that north of Loch Maree, where the biotite-gneisses and hornblende-schists of Meall Riabhach are superimposed on the sedimentary series of Letterewe, or (2) the structure may be fan-shaped, the rocks of Lewisian facies (No. 1), though apparently the highest, may in reality be the lowest, while the sequence of

the other groups may be deceptive. Of these hypotheses, the first seems the more probable. Indeed, the uniform characters of the Moine-schists, Nos. 3 and 5, and their persistence without modification throughout the folded area of Fannich, suggest the probability that their crystalline characters were developed prior to the Post-Cambrian movements. **Fannich Forest. (Mr. Horne.)**

The ground surveyed by MR. POCOCK in the same tract of Ross-shire lies partly to the east and partly to the west of the ground that has been mapped by MR. HORNE, and includes the same groups of rock. The eastern part of his area comprises a portion of the rough ground north and south of the lower end of Loch Fannich. Here the rocks have been found by him to be remarkably uniform in character and structure. They consist of flaggy quartzose gneisses alternating with dark-coloured biotite-schists, in vertical beds, having a general north and south strike. On the whole, the quartzose gneiss is predominant, but a well-marked zone of biotite-schist, with but few bands of quartzose schist, has been traced for a distance of about four miles across the area. On the western side of this micaceous zone the breadth of the vertical series of quartzose schists is a mile and a half. Beyond this, on the west side, the beds arch over abruptly, and rise into the great cliffs of Ben Aigean, which form so striking a feature as seen from the road to Fannich Lodge. On this cliff the strata dip somewhat steeply to the S.W., but they flatten considerably as they are traced round the escarpment on the north side of the Fannich Hills into the ground mapped by MR. HORNE, where their inclination falls to no more than 20°. At the top of the Ben Aigean cliff overlying the quartzose schists a slight synclinal fold holds an outlier of the Sgurr Mor biotite-schist (No. 4 of the Table on p. 12). The quartzose schists here as elsewhere belong to the typical "Moine schists" (group No. 5). The biotite-schist zone, just referred to as occurring to the east, is closely similar in character to the Sgurr Mor schist, and most probably is a mass of the same rock folded into the quartzose series to a depth of about 1,400 feet on a north and south axis. It is intensely puckered, and is full of twisted lenticles of vein-quartz. It is well seen on the top of Càrn na Bèiste, a mile east from the lower end of Loch Fannich, where it attains a maximum breadth of half a mile. The crag at the summit of that hill is formed by a prominent quartzose sub-zone, which stands up above the softer features of biotite-schist on either side. The same biotite-schist forms the summit of Ben Dearg on the north side of the Grudie River, and is also seen 1,400 feet below the top of the hill in the river section, but is there much split up by quartzose bands. The smaller breadth of the zone at this lower level may indicate that the bottom of the fold is not far below that point. Traced southwards into the ground surveyed by MR. PEACH, the biotite-schist rapidly splits up and dies out. **Loch Fannich and Loch Luichart. (Mr. Pocock.**

The quartzose gneiss on the east side of the biotite-schist zone resembles the Ben Aigean series in general characters, but is somewhat more massive, and in places contains thin folia of pink felspar. It rises into the prominent crag which forms the

eastern shoulder of Càrn na Bèiste. The zoisite-amphibolite-rock already referred to, as described by MR. GUNN from the biotite-schist, has been found abundantly in the quartzose-schist on two horizons on the Ben Aigean cliff, and also on the low ground to the east near the mouth of Allt a' Choin Idhir.

The western part of the area mapped by MR. POCOCK includes some ground to the south-west of Loch Fannich, in which Beinn nan Ramh (2,333 feet) is the most conspicuous mountain. On the western slopes of this high ridge he has found a group of granulitic quartzose mica-schists which, dipping to the east at about 20°, are finer-grained and more flaggy than the typical Moine-schists of the district to the east just described. There can be little doubt, however, that they represent some part of the Fannich and Luichart series. When the ground lying to the north has been surveyed in detail, MR. GUNN'S zones will probably be identified here also. So far as the mapping has yet gone, the biotite-schists appear to be here thinner and more split up by quartzose bands. From the river section, one mile east from Leckie, a belt of biotite-schist, about 600 feet thick, extends over the peaty plateau to the north. It is evenly foliated without much puckering, and may represent one of the micaceous zones which attain a greater development in the Fannich region owing to the extent to which their folia have been plicated. Above the biotite-schist in apparently ascending order, an alternating series of micaceous and siliceous schists passes up into massive granulitic quartzose gneiss. One or more ill-defined belts of biotite-schist occur in this series, the total thickness of which may be nearly 4,000 feet, measured from the top of the belt of biotite-schist near Leckie. The zoisite-amphibolite-rock is found occasionally here also in bands one or two inches thick.

The summit and eastern slopes of Ben Ramh are occupied by a complex group of gneisses of different character, which apparently overlie the Moine-schists just described. They are distinguished by the frequent presence of dark hornblendic patches and dykes. The most prominent member of the group, occupying by far the largest part of Ben Ramh, is a coarse flaky garnetiferous gneiss first found by MR. HORNE on Meall Dubh. In its most typical form it consists of coarse muscovite and biotite folia, is full of dark red garnets, and contains lenticles of pegmatite from a quarter of an inch to an inch in thickness. But it presents considerable variations of character. Some of its finer-grained portions contain little or no pegmatite and cannot be distinguished in hand specimens from the ordinary micaceous Moine-schists. Others display the pegmatite drawn out into parallel folia and in such large proportion that the rock assumes an acid character, while a third class presents muscovite developed almost to the exclusion of biotite. The pegmatites of this rock deserve special mention, as a few of the larger veins, which are several feet thick, contain a beautiful rock made up of large muscovite plates varying up to three inches in diameter set in a quartzose matrix which is crowded with small stumpy prisms of black tourmaline; a few of the tourmaline crystals attain a

length of four or five inches. The hornblendic portions of the flaky gneiss, though sometimes traceable as dykes for short distances, usually take the form of irregular rounded masses of eclogite. A boulder from one of them, found on the east side of Ben Ramh, contains a vein with crystals of black hornblende three quarters of an inch long. Loch Fannich and Loch Luichart. (Mr. Pocock.)

Closely associated with the flaky gneiss is a granitoid gneiss made up of coarse white quartzo-felspathic layers with intensely contorted micaceous folia. It is well seen on the eastern slopes of Ben Ramh, where it is folded up with the flaky gneiss on a general N.W. and S.E. axis. Further west several distinct outcrops of a similar rock occur, some of which pass into a fine-grained quartzose gneiss with thin folia and "eyes" of felspar similar to Mr. Gunn's "Acid gneiss" (No. 1). The basic portions of the granitoid gneiss usually appear as hornblende-schist dykes, traceable for short distances, and folded with the main mass of the rock. East and west of the main outcrop of flaky gneiss, but folded with it, are masses of quartzose gneiss belonging probably to the Moine-schist series, but placed in this group on account of the presence of hornblende-schist dykes. In many parts the rock is indistinguishable from the typical quartzose Moine-schist, whilst in others the occurrence of thin felspathic folia and "eyes" associates it with the Acid gneiss.

Only one example of later intrusive igneous rocks was observed. This is a small lamprophyre sill which occurs near the southern shore of Loch Fannich.

At the close of the work for the season among the Fannich mountains Mr. Horne moved into Easter Ross and continued his mapping of that district. The ground there examined by him included some small tracts of schistose rocks. In the neighbourhood of Rosemarkie these rocks rise up from under the Old Red Sandstone as the crystalline axis long ago described by Hugh Miller. The best section in the area mapped last year is to be seen on the shore, but the original characters of the rocks have there been greatly altered by the action of the great dislocation which extends from Loch Ness and the Great Glen up the eastern coast-line of Ross-shire. The rocks have been so brecciated that they break up into small angular fragments, and a fresh fracture is consequently difficult to obtain. They consist of flaggy granulitic biotite-gneisses with thin bands and lenticles of hornblende-schist and actinolite, traversed by numerous veins and irregular masses of a pink granitoid rock. The latter type of igneous material is well seen on the side of the road in Rosemarkie Glen. Easter Ross. (Mr. Horne.)

Another small area of crystalline schists was mapped by Mr. Horne on the west bank of the Beauly river along the western margin of the Old Red Sandstone. The rocks consist there of grey granulitic quartz-schists (quartz-biotite-granulites) with thin bands and partings of biotite-schist, the latter sometimes containing muscovite. Thin veins of lamprophyre occur in these schists near Aigas. Near the margin of the Old Red Sandstone, east of Glen Convinth, the schists consist of biotite-gneisses, Inverness-shire—Kiltarlity district. (Mr. Horne.

with thin highly-contorted folia of granitic material. This series is traversed by veins of granite and pegmatite which recall the type of composite gneisses in the east of Sutherland.

A small area of metamorphic rock to the north-west of Beauly, also mapped last year by MR. HINXMAN, is occupied by a series practically identical in lithological composition with the rocks of Upper Strathspey. These rock-types are also practically identical with those examined by MR. B. N. PEACH in the Loch Luichart district above referred to, as well as with those traced by MR. GRANT-WILSON far to the south at the head of Loch Eil on the West Coast. Rocks of similar lithological types have thus been identified in widely separated areas on both sides of the Great Glen; and it seems probable that these two groups will be found persistent throughout much of the unsurveyed parts of the Highlands.

Caithness.

(Mr. Pocock.) On the conclusion of the brief season during which mapping is possible in the Fannich Forest MR. POCOCK resumed his field-work of the previous year in Caithness, and mapped an additional area of the schists which in that county rise from under the wide undulating plain of Old Red Sandstone between Glut Lodge, the south side of the Morven range, and Braemore.

The rocks in this tract of ground were found to consist of (1) fine-grained granulitic quartzose gneisses and mica-schists, with granitoid folia and thin bands of granite; (2) coarse-grained rudely-foliated orthoclase-gneiss, with large crystals of pink orthoclase; (3) massive snow-white quartz-schist. The first of these groups is the same as that described in the *Summary of Progress* for 1897 as occurring near the granite mass in the Glut Water. A narrow belt of the same rocks is found in the Berriedale Water near Corrichoich, where their relations to the granite are similar. Occasionally the ordinary type of Moine-schist is met with, but most commonly the gneiss contains thin granitoid folia made up chiefly of quartz and felspar. In no case, however, have chilled margins been observed either in the folia or in the larger veins of granite. So thin are some of the granitoid folia that in hand-specimens the composite nature of the rock cannot be recognised. A striking resemblance to the "acid gneiss" of Loch Fannich is thus induced in the more quartzose portions of the schists, while the mica-schists, which become coarse and contain lenticles of pegmatite, approach in lithological character the flaky gneiss of Meall Dubh. The occurrence of coarse intrusive pegmatites may here be noticed. They are found in masses several feet thick, and consist of plates of muscovite two or three inches in diameter, with white felspar crystals set in a matrix of quartz.

The orthoclase-gneiss is found extensively on the low ground on the north side of Morven. It forms a belt which crosses the Berriedale Water at some distance to the west of Corrichoich and thins out eastwards between two masses of granite.

A small inlier of the same rock occurs within the Old Red Sandstone area, half a mile west of Braemore Lodge. The characteristic feature of the material is the presence in it of large crystals of orthoclase, varying up to two inches in length. The crystals are perfectly formed or show a graphic intergrowth of quartz, and are surrounded by folia of dark greenish mica. Augen-structure is frequently found, but in places the orthoclase-crystals are so thickly crowded that the foliation of the rock is almost obliterated. Though so different in lithological characters from the composite gneisses above referred to, it belongs to the same series and has a similar origin. This can be seen in one of the burn-sections at the foot of Morven. A mica-schist is there exposed of the Moine type with folia of coarse pink pegmatite, and thin dykes of the same material with large pink orthoclase cutting across the foliation. A similar rock has been described by the Director-General in his Memoir on the Old Red Sandstone* as occurring on the north side of the Scaraben Range. The quartz-schist appears in four separate masses in this area, the largest of which is the Small Mount on the west side of Morven. It is of uniform character throughout and quite distinct from the quartzose Moine-schist. It is composed almost entirely of quartz in folia a few inches thick, much folded and dipping at steep angles in the same direction as the Moine-schists. Sometimes a little white mica is found between the folia, with vein-quartz cutting across them. The quartzite is seen in contact with the Moine-schist on the north-side of the Small Mount, but in other places the junction is obscured by the unconformable overlap of the Old Red Sandstone. Each of the four masses occupies high ground, and the quartzite cannot be traced across the intervening low ground. They occur as outliers resting upon the Moine-schists, though they appear to be folded up with and conformable to the lower series. No instance of granite veins intruded into the quartzite has been observed. (Mr. Pocock.)

The granite mass, described in the *Summary of Progress* for 1897, from the hills west of Glut Lodge has now been traced southwards into the Berriedale valley. The lines of structure change somewhat abruptly about three miles south of Glut Lodge, from a north and south to an east and west direction. The granite is exposed in the upper reaches of the Berriedale water near Goberniesgeach, and passes in an easterly or north-easterly direction along the left bank of the river nearly as far as Braemore, whence it crosses the watershed into the Dunbeath valley and passes under the Old Red Sandstone. It presents the usual features, which have been described in former Reports. In this district, however, it is rarely foliated. Along its margin it is often coarse and highly micaceous, and it is cut by veins of more acid pink granite. The pink granite, which is a later intrusion, and is distinguished by the colour of its felspar from the grey rock just referred to, attains a considerable development on the north side of the Dunbeath Water, where it has

* *Trans. Roy. Soc. Edin.*, vol. xxviii. (1878), p. 369.

(Mr. Pocock.) furnished the materials of which the basement beds of the Old Red Sandstone are composed. It is to this later intrusion that the pink-pegmatites of the orthoclase-gneiss described above are attributed. An earlier basic intrusion was observed a short distance east of Goberniesgeach. It is a quartz-diorite, containing a little brown mica, and it appears to be of considerable extent, but has not yet been completely mapped. It is cut by veins of white pegmatite.

Dalradian or Younger Schists of the Scottish Highlands.

In continuation of the arrangement followed for some years past in the distribution of the field-work in the Highland region to the east of the Great Glen, a series of stations has been taken by the Surveyors, from Aberdeenshire in the north-east to Argyllshire in the south-west. In the upper part of the Valley of the Dee Mr. Barrow and Mr. Cunningham-Craig have prosecuted the survey of the high grounds to the north and south of the valley. Mr. Hinxman has carried his mapping further into the upper basin of the Spey and the Monadhliath Mountains. Further to the south Mr. Cunningham-Craig was occupied during part of the season in surveying certain tracts that remained to be completed in Perthshire. Towards the south-west, some parts of the crystalline schists came into the area surveyed by Mr. Kynaston around Glen Etive and Loch Awe. In the Oban district additional tracts of these schists have been mapped by Mr. Symes. On both sides of Loch Linnhe and Loch Eil fresh ground was broken by Mr. Grant-Wilson. Among the islands a considerable new tract in Jura was mapped by Mr. Wilkinson, and in the northern half of Arran the survey of the belt of schists was continued by Mr. Gunn. Each of these officers has furnished an account of the progress of his work, and their reports are here inserted in the geographical order just given.

Aberdeenshire.

Braemar. (Mr. Barrow.) In the district of Braemar surveyed by Mr. Barrow the same highly quartzose rocks described in previous Reports have been encountered, and have been found to be still disposed in isoclinal folds. In the great mountains of quartzite, which form so conspicuous a feature in the scenery of the Central Highlands, the limbs of these folds can be seen to be for the most part straight, and to be inclined at a high angle. This structure is displayed among the Ben y Ghlo Mountains up to a height of 2,400 feet. Further to the north, however, in the direction of Braemar, these straight limbs begin to "buckle," and this "buckling" continues till a series of approximately horizontal

minor plications is superinduced on the older vertical or straight-limbed folding, as may be clearly seen in the quartzite mountain south-east of Braemar. The structure thus produced is identical with that observed in the Moine-schists or eastern gneisses of Sutherland, Ross, and Western Inverness-shire. It is found over the whole of the district to the north of the Dee, though owing to the great number of normal faults, the horizontality of the bedding planes has been considerably disturbed. An examination of scar-faces, such as those seen in the Sluggan Burn, indicates that, in spite of the horizontality of the bedding, some distinctly recognisable band may be found to ascend vertically through the mass of rock. At the top of the main quartzite a peculiarly fine white siliceous band of a very distinctive character forms a readily traceable horizon, by means of which the total original thickness of the pink and grey quartzose rocks above the quarzite proper can be proved to be really small—probably not more than 30 feet. This white band is met with repeatedly in every direction, and its constant repetition indicates that in spite of the great area which they cover, and the apparently great thickness which they reach, these quartzites must be reduplicated again and again upon each other. As in the area south of the Dee, the highly quartzose rock above the true quartzite is often replaced by the black schist, or rather, in this part of the district, by hornfels, with its associated tremolite-rock. The hornfels rocks, or dark schist, as well as the pink and grey quartzose rocks, both rest on the top of the white quartzite, and one occurs to the exclusion of the other. The little band of tremolite rock, originally an impure limestone, has proved of great importance as a stratigraphical horizon. By means of it the quartzose rocks above which it occurs can be proved to be a continuation of the Central Highland Quartzite, in spite of the difference in aspect which the "Moine"-structure imparts to the rocks as a whole. Thus the tremolite-rock, taken together with the white band at the top of the quartzite, affords evidence that the original thickness of this part of the Highland series was small. After walking for hours across the line of strike, with the dip persistently in one direction, the observer may end at exactly the same horizon as that from which he started. Braemar. (Mr. Barrow.

Attention has been drawn in previous Reports to the occurrence in the Highlands of rocks that present a brittle cross-fracture, are entirely devoid of true schistosity, and display a structure and composition identical with those found in rocks that have been invaded by or engulphed in granite masses. In the course of the field-work last year this type of alteration has been observed to be largely developed in what was originally a dark shale that accompanied the limestone. The metamorphism along what may be conveniently called the central part of the zone of alteration has resulted in the production of a dark cordierite-hornfels with a resinous cross-fracture; a rock of this type extends in a series of disconnected masses probably as far north as the area formerly surveyed by Mr. Hinxman, about Loch Builg.

naı.- Barrow.) As the cause of this type of alteration is a matter of dispute, a summary may here be given of the facts observed regarding it in the Braemar district. While rocks that were originally grey shales or calcareous shales frequently show this type of alteration, those that were originally sandy shales seem rarely to show it, but are almost always more or less schistose, or in highly crystalline areas, gneissose. Some connection may therefore be presumed to exist between difference in mode of alteration and difference in composition. So far as MR. BARROW'S experience has gone, the "hornfels" type of alteration has been found by him only in those areas of the Highlands where the portion of the older granites occurs that was intruded prior to the schistosity-movements, such as the well-known Ben Vuroch granite. The indurated aspect of this type no doubt often extends considerably beyond the area where the igneous material appears at the surface, but the careful examination of a large area has served to point out a close connection between the early intrusions and the hornfels type of alteration.

In illustration of these conclusions reference may here be made to the Braemar district, in which a train of intrusions of the early intrusive material has been traced along a line that extends for some 30 miles from the lower end of Glen Tilt to some distance beyond the valley of the Dee. This line is as straight as an arrow, and in every instance the more distinctly contact (thermometamorphic) type of alteration is met with around these intrusions. The effect of the uprise of the plutonic material on the rocks penetrated by it has naturally depended upon the amount of igneous material present, and in the Braemar area where these intrusions are small in amount MR. BARROW infers that the granite, being injected before the development of the schistosity of the rocks, simply indurated the grey and calcareous shales, but did not indurate sandy shales. Hence the indurated shales were afterwards able to resist the schistosity-movements, while the non-indurated shales did not possess cohesion enough to do so. Owing to the enormous force of these movements the margins of an area of early induration are always broken down, the hornfels-rock being cut up into lenticles. This lenticular dislocation is an extremely common feature of areas in which the hornfels-type of alteration occurs. From a comparison of the broken down part with the unmoved hornfels-rocks it is inferred that the crystallisation which they display has mainly taken place since the breaking down or schistosity-movements, for both kinds of rock are practically equally crystalline. A small patch of the early induration has escaped crushing quite close to the margin of the newer granite of the great Cairngorm tract. Comparing this patch with the hornfels-rock nearer the Bridge of Dee area, MR. BARROW has noticed that the contact-type of alteration (felspar-hornfels) is less pronounced close to the great mass of granite than it is at a distance of three miles off. Again he has observed that in Glen Cluny there is still clearer evidence that the Lochnagar granite, which is also one of the younger intru-

sions, has not produced the hornfels type of alteration. Where the older granite comes to the surface at Newbigging, about four miles south of Braemar, the indurated or hornfels aspect of the altered grey shale (now andalusite hornfels) is well marked.

Braemar. (Mr. Cunningham-Craig.)

In continuing his work northwards from the line of the river Dee in the Braemar district, MR. CUNNINGHAM-CRAIG observed some marked differences in the characters of the crystalline schists from those previously described. He found the change to take place somewhat suddenly along a line which, in the neighbourhood of Braemar, coincides practically with the course of the Dee.

As far as can be observed, this change in the character of the rocks cannot be accounted for by either a fault or an unconformability, but appears rather to be due to a comparatively sudden alteration in the character of the metamorphism. To the northward of this line the rocks appear to have suffered to a much greater extent from shearing, prior to granulitization. In consequence, the normal rock-type of this area is a banded and flaggy granulitic gneiss, the different bands being frequently sharply defined, and varying considerably in composition. Dips are almost invariably low and undulating.

Except for one small exposure immediately north of the alluvial flat at Braemar, the limestone and black schist, already described in former Reports, do not appear in this area, till brought up by the Clais na Fhearna fault in Glen Lui, six miles to the westward of Braemar. The prevailing type of rock is a granulitic biotite-gneiss, essentially siliceous, but frequently containing very felspathic bands. Muscovite is sometimes conspicuous, and is often developed in felted plates on the foliation planes, giving the rock a schistose character. Biotite is invariably present, the quantity varying in different bands. What is known as "colour-banding" (*Summary of Progress* for 1897, p. 48), the presence of thin laminæ of heavy minerals, concentrated and deposited by current action, may occasionally be detected.

Certain horizons are marked by thin bands of quartzite closely resembling in texture the saccharoid quartzite of the area south of the Dee, but a parallel structure is more prevalent, muscovite having been developed on the foliation planes at the expense of the felspar.

The relations of this series of flaggy granulitic biotite-gneisses between the Dee and the Cairngorm granite (described in last *Summary of Progress*, pp. 47–52) to the limestone and black schist, are not clearly seen in the eastern part of the area surveyed by MR. CUNNINGHAM-CRAIG, the section near Braemar, where calcareous and argillaceous rocks are exposed, being much complicated and obscured by igneous intrusions. The lower part of the section, however, displays an impure sheared quartzite, which appears to be in conformable succession with the calcareous rocks.

Sections in Glen Lui and Glen Derry, six miles west of Braemar, show that in traversing this series of gneisses we are never far from the horizon of the limestone. A fault, running

Braemar. (Mr. Cunningham-Craig.)

approximately north-east and south-west, brings up the limestone with an included fold of black schist, and the calcareous rocks are folded with the gneiss in precisely the same manner as the quartzite and limestone are folded in the Glen Ey area, the only difference being that the folds in the northern tract are approximately horizontal. At one point a thin band of quartzite is noticed between the margin of the limestone and the gneisses.

The series of granulitic flags and schists thus appears to take the place of the quartzite, and as no evidence has been found of an unconformability between the isolated quartzite bands and the flaggy gneisses, the two types of rock would seem to be equivalents. A section south of the Linn of Dee, approximately on the line where the effects of shearing become more conspicuous, confirms this inference by exposing several bands of saccharoid quartzite, folded and apparently intercalated with massive bands of biotite-gneiss, which do not exhibit a banded or flaggy aspect. In the area for some distance to the southward, similar intercalations are to be seen, the quartzite gradually becoming more predominant. Northward, on the other hand, the quartzite becomes less conspicuous, and the rocks lose their massive character under the influence of shearing forces, so that they appear as flaggy and banded gneisses and schists. The evidence hitherto obtained points therefore to the conclusion that these granulitic and flaggy gneisses are the representatives of the quartzite, which seems to have undergone some change in its original lithological character as it stretched towards the north, whilst it has also partly, no doubt in consequence of its change in composition, suffered to a greater extent from the effects of the shearing forces.

The cause of the greater shearing in the northern parts of the district may probably be looked for in the bending over and flattening of the isoclinal folds, along a line to the south of and parallel to that which marks the southern limit of the shear area. Such a bending of a vertically packed isocline must necessarily have been accompanied by shearing stress in the horizontal limb.

In Glen Lui, immediately above the limestone escarpment, about thirty feet of a band of peculiar granulites are exposed between the limestone and the granulitic gneiss. These rocks are finely-banded, rich in alkali-felspar, and destitute of quartz, while their other constituents give evidence of such an alkaline composition as to suggest an originally igneous origin for their material. Mr. Teall, who examined several specimens, has determined ægirine in one band, and this mineral has since been detected in other bands. Biotite and a pale garnet are always present, while muscovite and epidote characterise certain bands. Near the limestone a band of actinolite-schist, possibly representing the impure edge of the limestone, has been recognised, while a pale tremolite-schist may also be seen among the felspathic granulitic bands. It is hoped that subsequent examination and research may determine the origin of these granulites. Meanwhile it is clear that the felspathic bands have become

incorporated with material at the margin of the limestone during the movements and metamorphic processes which preceded granulitisation. The following determinations were supplied by MR. TEALL from his examination of some of the specimens:— Braemar. (Mr. Cunningham-Craig

"[8216.] Epidote-granulite. A somewhat coarse-grained granulitic or granular aggregate of alkali-felspar, epidote and green biotite, with a colourless garnet, sphene and apatite as accessories. The apatite occurs in hexagonal prisms and has all the characters of the apatite of igneous rocks."

"[8217.] Ægirine-granulite. Alkali-felspar, yellow garnet, ægirine and biotite, with magnetite in sharply defined octahedra, apatite and probably sphene as accessories. The garnet occurs in more or less idiomorphic crystals and as aggregates. It resembles in colour the pale tints of the melanite of the borolanites. The ægirine is bright green; it can be definitely determined by examining the powder of the rock. The prismatic fragments give nearly straight extinction and the greatest axis of elasticity is approximately parallel to the long axis of the fragment."

"[8273.] Mica-schist. Alkali-felspar similar to that in the above rocks, white mica, chlorite and colourless garnet largely replaced by chlorite; with epidote, sphene and apatite as accessories.

"The distinguishing feature of the group is the presence of an alkali-felspar containing both potash and soda, and therefore probably belonging to the anorthoclase group. This taken in connection with the absence of quartz distinguishes the group from all the other Highland schists. The presence of ægirine and of a garnet allied to the garnet of the borolanites is another peculiar feature."

The younger Granites of the Grampian Hills.

While working in the Braemar district last year MR. BARROW and MR. CUNNINGHAM-CRAIG have been able to add to our knowledge of the characters of the younger masses of granite which occupy such extensive tracts of the central Grampians. Each of these observers has furnished the account of his own observations. (Mr. Barrow

In the area examined by MR. BARROW he has observed four rock-types among the younger granitic intrusions: 1, Diorite; 2, the great masses of red granite (Cairngorm, Lochnagar); 3, residual white or pale granite with biotite; 4, residual white or pale granite with muscovite and a little biotite.

The Diorite varies much in composition, and appears repeatedly over an area bounded to the north by the Cairngorm granite mass, to the south by the Dee, and to the west by a line drawn from Invercauld House due north to the head of the Gairn. In the western part of this tract the intrusions of the rock are extremely numerous. They vary in size from patches only a few yards broad to masses 100 yards broad and a quarter of a mile long. Further east, while small patches are still fairly frequent, the larger attain greater dimensions till they eventually merge into one of the great masses of diorite which occur at intervals on the north side of the Dee from Braemar to the coast. The abundant small patches may be regarded as simply projections from the upper surface of a large mass which must extend for a considerable distance over this district at no great depth below the present surface.

arrow.) The acid residual material (3 and 4) is of special interest. It occurs as a great number of small intrusions, which are usually coarsely crystalline in texture up to their margins. These small intrusions of the biotite-bearing granite are so common on Cairn Liath as to closely simulate the phenomena of permeation, so often shown by the older granites; the chief difference being that they are clearly intrusions, and do not present the appearance of being part and parcel of the altered rocks, as the older granite so frequently does. In many cases they seem to have fused the edges of the diorite, when in actual contact with it, and then the pale granite contains numerous wedge-shaped sphenes, obviously derived from the diorite in which the sphenes are abundant. Moreover, the granite in such cases is well foliated. The tendency to foliation is not, however, confined to the rock at the edges of the diorite, it occurs over the whole southern part of this area, being specially well shown to the east of Braemar.

From its whiteness, hardness, frequent foliation, and the presence in it of minerals hitherto only met with in the older granite, this granite was classed with the latter rock in the *Summary of Progress* for 1897. This view of its relations has now been abandoned by MR. BARROW, for he has since found that, notwithstanding its resemblance to the older granite, it actually intrudes into and must therefore be younger than the diorite, which can be proved to be much later than the older granite. Along its junction with the diorite this granite, which assumes so deceptive a likeness to the material of the earliest intrusions, passes insensibly into the more basic rock, and includes a considerable number of the wedge-shaped sphenes, so characteristic of the latter in this area. A good instance of this passage is met with on the foot-path from Invercauld to Loch Builg at the north end of the Invercauld woods; and similar passages may be seen further north. The hard white sills of the Braemar area, into which this pale granite passes, were also supposed to belong to the earlier granites; but there can now be no doubt that both should be considered members of the newer granite series.

With regard to the origin of this pale granitic material, MR. BARROW is disposed to look upon it as a residual acid part of the younger granite, which was the last to separate out. Like the residual parts of the older granites, it shows pegmatite or graphic structures in a great number of instances. It again resembles the pegmatitic material of the older granites in the local abundance in it of garnets and epidote, though these minerals are entirely absent from a considerable number of the small intrusions. So far as at present known the garnets occur in no other part of the newer granite, nor has this pale acid material been observed to exist in considerable quantity in any other part of the Highlands.

The acid material containing white mica often makes its appearance inside the great Lochnagar mass of granite, but is never coarsely crystalline. Its junction with the main body of

granite is always sharp in a hand-specimen, and its margins are fairly fine-grained. The tendency to minute subdivision, so marked in the area invaded by the diorite, is entirely absent in the granite. (Mr. Barrow

The Cairngorm Granite.—A large part of this extensive intrusion has now been mapped. Its northern and western tracts have been examined by MR. HINXMAN, as stated in former Annual Reports. MR. BARROW has touched it on its eastern border, while MR. CUNNINGHAM-CRAIG has last year entered upon its southern heights.

The small part of the Cairngorm granite mapped last year by MR. BARROW is situated about the head of the valley of the Gairn. The rock is there of the usual red colour, and is composed of potash-felspar, quartz, plagioclase, and a little brown mica. It contains more potash-felspar and less brown mica than either the Lochnagar or the Kincardineshire masses, and it is on the whole slightly more acid. Like those masses it is always much decomposed near the surface, so that a good specimen for microscopic examination is not readily procurable. Although the actual junction of the igneous rock with the adjacent altered sediments is not to be seen, a narrow gully has been eroded along the boundary line for more than half a mile, exposing the bare granite and the altered sediments within a few feet of each other on opposite sides. The granite is apparently somewhat coarse in grain up to its margin, but along its borders there occurs a great number of more recently intruded patches of the peculiar soft red granite, full of cavities, that is so abundant on the margin of the granite near Ballater. This substance varies in texture from a markedly coarse rock to a comparatively fine one, but no evidence has been obtained to account for the curious variation in texture. The adjacent altered sediments are singularly free from igneous material. No trace of any permeation of these rocks by material proceeding from the great granite mass has been detected here. A specimen taken six feet from the edge of the granite has been found to be identical in crystallisation with a specimen of similar composition taken two miles distant from the granite. In this district therefore the granite does not appear to have produced any appreciable metamorphism of the adjacent rocks.

In the area of the upper basin of the Dee, mapped last year by MR. CUNNINGHAM-CRAIG, other masses of the younger granite intrusions were examined. In the very heart of the Cairngorm Mountains, near the head of Glen Derry, he came upon an irregular mass of basic diorite, covering nearly a square mile of ground. On its northern and southern sides this mass is bounded by granulitic biotite-gneisses and granulites, while on the eastern and at one point on the western side it is in contact with the Cairngorm granite, which also surrounds and includes the granulitic gneisses. The intrusion of this diorite has taken place prior to that of the granite, and where the two rocks come together a good example of "mélange"-junction is seen; the granite (Mr. Cunningham-Craig.)

has apparently fused the margin of the diorite, and considerably modified the composition of the affected zone by the introduction of acid material. Thus, in passing across the junction from granite to diorite, the granite is observed to become finer in grain, and to contain more biotite, this is succeeded by a rock which MR. TEALL has examined microscopically and describes as "biotite diorite composed of zoned and more or less idiomorphic plagioclase (oligoclase-andesine), biotite, interstitial quartz and iron ores," while, farther on and throughout the main mass of the diorite, the rock has been found by the same observer to be composed of "labradorite, biotite, augite, fibrous hornblende, in large part, if not entirely after augite, and iron ores," and may be described as an "augite diorite."

In the thirteen square miles of Cairngorm granite that were surveyed last year by MR. CUNNINGHAM-CRAIG, three types have been recognised and separated by him. They appear to be of slightly different ages, but their relations to one another are not as a rule clearly shown. Their junctions with each other are usually marked by a sharp and distinct line which frequently shows itself at the surface in a hollow feature. In one case at least it can be proved that one of the types is intrusive in the main granite mass.

The chief body of the rock is a coarse red granite, consisting of orthoclase, oligoclase, quartz and biotite; the orthoclase frequently occurs in large, almost porphyritic crystals, showing Carlsbad twinning, while the scarcity of biotite, and the distinct development of the quartz are almost invariable characteristics. Near the margin of the mass, the texture of the granitite becomes finer, and the quartz occurs in rounded blebs, with a tendency to idiomorphism, while in the heart of the mass the quartz is gathered into dark aggregates which appear very prominent, owing to the clear nature of the mineral. It is as a lining to drusy cavities in micro-granite veins in this coarse granite that the "cairngorm" crystals are found.

The second type is a very fine granite or micro-granite, consisting of oligoclase, orthoclase, quartz, biotite, and muscovite. The muscovite is not present in such quantity as the biotite, and the orthoclase is often moulded upon, and includes more or less rounded grains or crystals of quartz. The rock not infrequently contains porphyritic crystals of quartz, and others of orthoclase showing Carlsbad twinning. This type of granite forms the summit of Beinn a' Bhuird, and is exposed chiefly on the high ground, as in Coire Ruaridh and Beinn Bhreac. At the latter locality it is distinctly intrusive in the coarse granite, and hand-specimens showing the junction may be obtained. It is worthy of note that this fine granite closely resembles the veins and dykes with drusy cavities in which the "cairngorms" were formed.

The third type of granite is a pale pink or occasionally white medium-grained biotite-granitite. No large crystals of orthoclase have been observed in this rock, while the biotite is more abundant than in the other two types, and occurs in rounded

plates. In many respects this variety resembles the Auchindryne granite; and from its mode of occurrence the rock, which has only been observed on Beinn Bhreac, appears to be intrusive in the main or coarse granite; but its relations to the micro-granite are not clearly seen, though the two rocks are in contact near the eastern summit of Beinn Bhreac. (Mr. Cunningham-Craig.)

Some interesting evidence has been obtained concerning the form of the Cairngorm granite intrusion. The actual margin of the granite in the ground examined is only to be observed at one place (Lochan a' Bhata), where a tongue of granite with approximately vertical sides is exposed at a height of nearly 2,000 feet on the ridge between Glen Derry and Glen Dubh. Numerous veins and small irregular sill-like intrusions are there to be noticed in the metamorphic rock; but this tongue may perhaps be more correctly considered as an offshoot from the main intrusion, and not important as giving evidence of the form of the intrusion. The granite boundary, however, is found to be very distinctly V-shaped in all the larger valleys. Thus, in the upper part of Glen Quoich it recedes northward for upwards of a mile, while in Glen Lui and Glen Derry the indentation apparently due to the valley is even more strongly marked. In Glen Dubh the V-shape is less conspicuous, as the glen is smaller and narrower. The southern boundary of the granite on the western side of Glen Lui is the Clais-na-Fhearna fault, and the rock is much crushed and intersected with quartz veins in the neighbourhood of the dislocation.

These facts suggest that in the deeper glens we are approaching the lower surface of the granite mass, and though no direct evidence of sill-like intrusion on a large scale has been observed, the probable form of the mass of granite on its southern side may be inferred to be roughly that of a cake or sill, with vertical or highly-inclined edges.

Around the margin of the granite, whenever a good section is obtained, minute veins of granitic material have been observed in the metamorphic rocks. These are sometimes fine-grained, with the component crystals interlocking with the crystalline constituents of the country-rock, but occasionally, especially where the veins are larger, coarse pegmatite and aplite have been noted. None of these veins have been traced to their parent source; but from their occurrence contiguous to the granite margin, and their similar composition, it may be inferred that they are offshoots from the main intrusion.

With regard to the metamorphic effects of the intrusion of the Cairngorm granite, MR. CUNNINGHAM-CRAIG reports that though the surrounding quartzose biotite-gneiss is not of such composition as to give very clear evidence of additional alteration by the younger igneous rock, a mass of felspathic gneiss, which is included between the Glen Derry diorite and the granite, is much more highly crystalline than the rock outside the granite area. Some granulite bands in this mass show such a high state of crystallisation as to simulate igneous material, and to suggest

Cunningham-Craig.) that "reconstruction" has taken place, more especially along those laminæ the mineral and chemical composition of which was most favourable to alteration under thermometamorphic processes.

The most interesting evidence of change, however, is afforded by the band of limestone and black schist on the eastern side of Glen Lui and Glen Derry. The limestone appears on the north-western side of the Clais-na-Fhearna fault, at a distance of nearly a mile from the granite which is displayed on the western side of the glen. From this point the limestone can be traced north-westward, approaching the granite boundary obliquely to the east of Derry Lodge, where it probably comes in contact with the igneous rock, but the ground is there entirely obscured by drift for some distance. In Glen Derry, a mile to the northward the limestone is well seen in the burn section at Derry Falls, at a distance of less than 300 yards from the granite margin. In the Glen Lui section, the limestone presents the characters that commonly show themselves in an area which has not been very greatly affected by thermometamorphism; the purer bands are grey and bluish in colour and are not conspicuously crystalline, while the impure bands are soft and friable, contain much free carbonate and show no signs of conversion into hornfels. At the north-western part of the exposure, thin bands of tremolite-schist appear which probably represent the altered selvage of the limestone. A band of black schist folded with the limestone has apparently suffered greatly from shearing, and contains quartz "eyes" with garnets; certain bands are filled with rusty crystals of kyanite, while others show large irregular aggregates of andalusite, but the rock is everywhere highly schistose and friable. The kyanite, andalusite and garnet are most abundant towards the north-western extremity of the exposure, that is, in the direction of the main granite mass. In the Glen Derry section, where the granite must lie very near, though the actual junction is not seen, the limestone is represented by a mass of hard, beautifully banded calc-silicate hornfels, only the purest bands containing free carbonate of lime, which also appears to decrease somewhat in quantity to the northern extremity of the section. Thin bands of white saccharoid limestone containing aggregates of a pale flesh-coloured garnet are noticeable, while in the impure bands pale green hornblende, wollastonite, epidote, idocrase and malacolite (?) were detected by Mr. Cunningham-Craig in the powder which he obtained by crushing samples of the rock, and which he examined under the microscope. His results have since been confirmed in a study of thin slices of the same rocks by Mr Teall, who has furnished the following notes of the microscopic characters of specimens taken from Derry Falls:—

"[8340.] Banded hornfels containing malacolite, wollastonite, alkali-felspar, sphene, quartz, and hornblende. The wollastonite occurs in radiating tufts and the felspar in granular aggregates and large irregular micro-poikilitic patches. The malacolite in certain parts of the slide also occurs in large micro-poikilitic grains."

"[8343.] A mottled calc-silicate hornfels containing large patches of pale brown idocrase and garnet. The rock contains also malacolite and wollastonite." (Mr. Cunningham-Craig.)

"[8344.] White saccharoid marble containing brown spots and bands of idocrase and garnet. Wollastonite and malacolite are also present."

Though the black schist is not exposed at the section just referred to, some thin infolds of more argillaceous material which make their appearance, have to a great extent lost their schistosity, and appear as hard dark-coloured bands containing kyanite. The impure siliceous beds, which are here folded with the limestone, have had their bedding practically obliterated, so that there is some difficulty in observing their actual dip. This alteration in the mineralogical character of the calcareous band cannot reasonably be accounted for by a change in the composition of the material, for no direct evidence has been detected that such a change has taken place. The alteration is precisely what is ordinarily to be observed in rocks of this nature as they approach a large granitic mass. As no igneous intrusions other than the Cairngorm granite appear in the neighbourhood, the inference may be drawn that this conversion of the calcareous and associated rocks into hornfels and the development of the concomitant minerals that are characteristic of this type of thermo-metamorphism have been caused by the intrusion of the Cairngorm granite. In this connection it may be noted that in the hornfels area of Glen Ey and Corriemulzie, where the black schist is so distinctly affected by additional thermo-metamorphism (*Summary of Progress* for 1897, p. 53), the limestone bands do not show an alteration to calc-silicate hornfels such as that above described, and in fact do not seem to have been greatly affected mineralogically.

To the north of Braemar a sill of granite with accompanying subsidiary intrusions closely resembles in composition and in general appearance the Auchindryne granite which is exposed in and about Braemar, and the age of which in relation to the surrounding rocks has been for some time under consideration. This sill extends over the top of Creag a' Chleirich for upwards of a mile in a south-south-west direction, with a distinct dip to the south-west, and reaches nearly to the alluvium of the Dee valley. At its southern end, and again on the north-west side, the mass is bounded by fault-lines along which the granite appears to have been intruded. The sill is somewhat irregular in shape, and attains a thickness of nearly 100 feet. Exposures being plentiful, and easy of access, clear evidence has been obtained, not only as to the relative age of this intrusion, but also as to that of the compact quartz-porphyry sills of the unusual type characteristic of the Braemar district. Mr. Teall describes the rock of the southern part of the mass as a "medium-grained pink granite, comparatively free from ferro-magnesian constituents, and essentially composed of oligoclase, micro-perthite and quartz. Its alkali felspar is abundant, and occasionally shows a very fine microcline structure. Small patches of micro-pegmatite occur in it, and biotite is present in small flakes."

. Cunningham-ig.)

Though more acid in composition, the rock presents several of the features characteristic of the newer Highland granites; it has evidently been intruded since some of the north-east and south-west dislocations; the alkali-felspar is frequently moulded upon the quartz, and the biotites, when examined microscopically, are seen to contain the characteristic needles of apatite, which have been described as specially typical of the newer granite. By its composition, character, and appearance, this granite can be identified with the granite exposed in Auchindryne, immediately south of the Dee. The small sills and tongues associated with the Creag a' Chleirich sill show none of the protoclastic structures which have been observed in the minor intrusions associated with the Auchindryne sill, but the larger masses are almost identical, and cannot be distinguished as of different age on that account. In what follows, the Auchindryne sill and the Creag a' Chleirich sill will be spoken of together as the "Auchindryne Granite."

Traced south-westward the granite sill becomes finer in texture, and passes gradually into a sill of compact quartz-porphyry with chilled edges, identical with those sheets which so frequently appear in the area south-west of Braemar, and the age of which has not hitherto been determined. Specimens intermediate between granite and quartz-porphyry may be obtained, showing crystal groups included in a matrix, which becomes gradually finer to the westward, till, a quarter of a mile from the granite, the edge of the quartz-porphyry sill assumes the aspect of a fine flinty felsitic rock, containing a few small phenocrysts of quartz and alkali felspar.

Mr. TEALL has examined specimens from this "passage rock," which he finds to be rich in alkali-felspar with microcline structure; the matrix is often micropoikilitic, and the structure may be described as "half-porphyritic." The ground-mass of the quartz-porphyry sill to the westward is micropegmatitic, while a few small idiomorphic garnets occur in the chilled margins.

The Creag a' Chleirich sill is associated with numerous minor sills and tongues of granite, which are exposed on the hillside beneath the main mass, while thin granitic veins and strings become so abundant in places that the metamorphic rock may almost be said to be permeated with igneous material. These veins are sometimes coarse and pegmatitic, sometimes fine-grained: in certain places they show clean-cut junctions with the country rock, while in others there appears to have been an interlocking of the crystalline constituents of the igneous and metamorphic rocks, along the line of junction. The composition of the veins does not appear to vary greatly, but to be practically identical with that of the granite.

These veins and minor intrusions form another link with the phenomena already observed south of the Dee, especially in the Clunie section, where the similar tongues and veins only differ by usually exhibiting a faint parallel or "round-grain" structure. None of the tongues, veins or sills of granite material in the ground north of the Dee show any signs of parallel structure.

In Glen Slugain, north-east of Creag a' Chleirich, several intrusions of similar pink granite have been noticed, but they all occur at a low level and cannot be traced for any distance. To the westward of the Auchindryne granite no other plutonic rock appears at the surface till the Cairngorm granite mass is reached. That vast body of eruptive material lies, as already mentioned, on the farther (and apparently the upthrow) side of a large fault. Quartz-porphyries, on the other hand, are very numerous, and may be traced in parallel sheets, sometimes for a distance of two miles along the hillsides. These sills have a low general dip to the south-west, and increase in number in that direction. The granite sill of Creag a' Chleirich also dips to the south-west, and here it may be pointed out that the granite intrusions appear to have a vertical as well as a horizontal limit; the granite is exposed on comparatively low ground, though rising to a height of 2,000 feet on the summit of Creag a' Chleirich, while the quartz-porphyry sills to the westward are exposed at a height of over 2,500 feet, and on Creag Bhuilg, two and a half miles west-south-west of the granite, reach a height of over 2,000 feet. At a distance of four miles west of Braemar, the quartz-porphyry sills are thinner, less numerous, and have evidently been more quickly cooled, while at a distance of four and a half and five miles westward they are represented by a few thin irregular felstone intrusions, of which the material resembles that of the chilled margins of the quartz-porphyry sills. In the area to the south-west of Braemar the sills continue for a much greater distance. (Mr. Cunningham-Craig.)

From these observations it may be inferred that the igneous intrusion has taken place from the eastward and north-eastward, so that in passing westward we are receding from the parent source of the eruptive material, and coming into areas wherein the cooling of the thinner molten injections took place more rapidly. It is a significant fact that in thus moving westward we pass from an area of hornfels-alteration into one where no proofs of additional thermometamorphism are forthcoming.

In the course of the survey of the ground north of the Dee, it has been observed that argillaceous and calcareous rocks, which are seen in contact with the Creag a' Chleirich granite sill, have been intensely altered by that intrusive sheet, the black schist being converted into a compact hornfels, and the calcareous beds being altered to a hard, banded, calc-silicate rock.

Evidence of faulting is well-marked in the area north of the Dee; the Glac Anthon fault has been traced to the north side, where it apparently splits into two dislocations, the principal one making a very deep gully (Clais a' Chait) in the ridge between Glen Slugain and the Dee Valley.

Reference has already been made to the Clais-na-Fhearna fault, which brings up the limestone on its north-westward side and forms a very wide and deep gash in the hillside between Glen Lui and Glen Quoich. There are many subsidiary faults and crushes branching from and parallel to this great line of movement, and the rocks are veined and shattered for some

[r. Cunngham-aig.)

distance on either side. Part of the movement along this line of dislocation has taken place since the intrusion of the Cairngorm granite, which on the western side of Glen Lui forms the north-western face of the fault, and is full of veins and minor crushes in its neighbourhood.

[r. Hinxman.)

Though MR. HINXMAN was not engaged last year in mapping any portion of the Cairngorm granite, he has examined so much larger a tract of it than any one else that it has been thought desirable to obtain from him a brief statement of his experience in tracing the relation between the intrusive mass and the surrounding rocks, and to insert this statement in the present *Summary of Progress*, together with the reports of his two colleagues. He remarks that the effects produced by the Cairngorm granite have been found by him to be most marked in the regions occupied by the rocks of the Banffshire series, which had undergone far less previous alteration than the schistose rocks to the west of them. In the western Cairngorms and the Monadhliath Mountains the granite was intruded into rocks that were already in a high stage of crystallisation, and the schists and gneisses of Upper Strath Spey consequently show little or no alteration compared with that produced on the less modified slaty schists and limestones of Banffshire and Aberdeenshire.

The limestones of Glen Avon, though fairly crystalline in character throughout, show increasing metamorphism as they approach the granite. Marmarosis, and the conversion of the impurer portions of the rock into tremolite and malacolite-rock, and malacolite-hornfels (slides 5454, 5456 and 5449 of the Geological Survey Collection) can be observed along the left bank of the Avon at Inchrory, in Glen Builg, on the slopes above Loch Builg, and in Glen Loin in the Glen Avon Forest.

Mineralization, including the production of garnet (green and brown), idocrase and other contact-minerals, is best seen in the small inclusions and outcrops that are found within and close to the granite on the Baddoch in the Braes of Abernethy, on Ben Avon, and in Glen Gairn. At the last-named locality patches of highly mineralised limestone occur within and along the margin of the area of tonalite that has been regarded as a more basic portion of the Cairngorm granite intrusion.

The band of mica-schist that runs south-east from the Caiplich Water to the Linn of Avon affords an example of progressive metamorphism due to the Cairngorm granite. Starting as a fine-grained, flaggy mica schist or phyllite, it becomes more crystalline and gneissose in character as it approaches the granite, until at the Linn, where it forms a narrow tongue almost enclosed by granite, it passes into cordierite-gneiss.

The "black schist" along the edge of the granite in Glen Builg, and on the hillside above Loch Builg, shows alteration of the hornfels type. Similar alteration is seen at Knockan and Nethertown in Glen Livet, where the black schist approaches the Glen Livet granite mass. Mention may also be made of the

development of large crystals of andalusite and staurolite in the black schist of Glen Tervie near the edge of the Ben Rinnes intrusion, an outlying mass of the Cairngorm granite. These crystals have been developed since the last movements that produced the "puckering" of the schists. (Mr. Hinxman.)

Inverness-shire.

Strathspey. (Mr. Hinxman.)

The region of Badenoch, in the upper part of the wide basin of the Spey, has been further surveyed during last year by MR. HINXMAN, who has found there the usual metamorphic rocks of the Central Highlands, with their associated igneous intrusions. His continued examination of the area of Glen Truim, along the upper course of the Spey, and in the Monadhliath mountains to the north of that river, has shown that the two types of rock described in former *Reports* are still persistent over a wide area, and can be readily differentiated. Broadly characterised as (1) Muscovite-biotite-gneiss and (2) Flaggy quartz-biotite-granulite, they present several further local variations. The former type includes garnetiferous mica-schist; "spangle"-schist in which white mica occurs in large scattered crystals lying at an angle to the planes of foliation; and coarse gneiss with crumpled folia, in which biotite is the predominant mineral. The quartzose series varies from a fine-grained granulitic biotite-gneiss, of which the black mica is an abundant constituent, to a highly siliceous flaggy schist or quartzose flagstone.

Two systems of plication appear to obtain in this area. The rocks have been subjected to rapid isoclinal folding, and, in addition, have been thrown into a series of wide undulations that often lie at a very low angle. This complicated structure renders it difficult to determine the relative position of the rocks to one another in the area under consideration.

Evidence was last year obtained of the continuation of the Loch Ericht fault along the course of the River Truim. This powerful dislocation, which shifts the outcrop of the Moor of Rannoch diorite near Loch Tulla for upwards of two miles, and has determined the position of the hollows occupied by Loch Laidon and Loch Ericht, enters the valley of the Truim a short distance below Dalwhinnie Station. The breccia and other signs of fracture, seen at several points along the course of the stream above Crubanmore and below Etteridge Bridge, indicate the position of the fault as far as the Bridge of Truim; its further course being concealed beneath the wide alluvial stretches of the Spey.

Several sills of the Glen Tromie porphyry have been observed by MR. HINXMAN in the lower part of Glen Truim, and one has been mapped by him on the slopes of Tom dubh-glaic in the Monadhliath range, the first observed occurrence of this rock to the north of the Spey. These sills are, as a rule, similar in character and composition to the porphyries from Glen Tromie, described in detail in the *Summary of Progress* for 1897. In

Strathspey. (Mr. Hinxman.)

one of the Glen Truim sheets, however, the phenocrysts of quartz and felspar are sometimes entirely absent, and the rock becomes in parts completely felsitic.

The opinion expressed last year (*Summary of Progress* for 1897, p. 56) that these quartz-porphyry sills represent the later phases of the Cairngorm granite intrusion, has been strengthened by the evidence obtained this year in Glen Truim. The veins of coarse muscovite-pegmatite, so abundant in the schistose rocks in that district, are distinctly cut by the quartz-porphyry sills; and therefore, whatever may be the relation in point of age of these pegmatites to the Cairngorm granite, they are prior to the intrusion represented in this region by the quartz-porphyry.

An acid igneous rock, showing remarkably fine spherulitic structure, has been mapped along the summits of Carn Dearg Mor and Sgorr Dearg, the high ridge lying between Glen Feshie and Glen Bhran. The rock is bright-red in colour, and generally felsitic in character, but often contains small dihexahedral crystals of quartz. The spherulites can hardly be detected under an ordinary lens in the fresh rock, but weathered specimens can be obtained in which they stand out in high relief, and present a most striking appearance. This felsite, as well as other small intrusions of a similar rock on the east side of Glen Feshie, often present a banded appearance, due, no doubt, to flow-structure.

The examination of these felsites under the microscope by MR. TEALL, shows that they contain no ferro-magnesian minerals, and have been formed from a very pure quartzo-felspathic magma, resembling that which under different physical conditions, has given rise to pegmatites. When phenocrysts are present, which is by no means always the case, they consist of quartz, turbid felspar, and micro-pegmatitic intergrowths of these two minerals; similar to those observed in the Tertiary spherulitic felsites of Druim-na-Eidhne in Skye. The quartz-phenocrysts occur as bipyramidal crystals and corroded grains. The spherules are rather less than 1 *mm.* in diameter, and usually have a light-coloured core with a darker periphery, but show no radial structure.

It may be worth noting that microscopical examination of a specimen from a thin vein of Cairngorm granite, close to the edge of the main mass in Coire Garbhlach, has revealed the presence of abundance of fresh microcline in conjunction with turbid oligoclase, quartz and biotite.

Lamprophyre sills, of a later date than the acid intrusions, are abundant among the schistose rocks of Badenoch. They frequently occur at the base of the steep isolated crags so common in this district, and seem by their superior hardness to have tended to determine these prominent features.

Certain thin sills of much decomposed basic rock found in the quartz-schists on the east bank of the Spey at Aikenway (Sheet 85 of the one-inch map) have been identified under the microscope as typical camptonite.

Perthshire.

Strathyre and the Trossachs. (Mr. Cunningham-Craig.)

Besides the ground surveyed by him in Deeside already described, Mr. Cunningham-Craig has continued, during part of the working season, the survey of the region of Strathyre and the Trossachs. The stratigraphical succession reported by him in the last *Summary of Progress* (p. 57), for this part of Perthshire, has been found to hold good over all the ground that has since been mapped. The various groups of that succession preserve their lithological characters with little change over wide areas, though there appears to be some local thickening and splitting up of the coarser grits.

The Aberfoil slates, which are well seen about the foot of Loch Lubnaig, consist of several bands, alternating with fine gritty beds, which show an indistinct cleavage; each slate-band can be distinguished by its colour, thickness, and the lithological characters of the beds with which it is associated. There is no evidence of repetition by folding.

To the south-east of the slate-bands, and apparently below them, grits of a totally different character from those to the north-west are observed. One of them, containing felspar and quartz pebbles in a fine chloritic matrix, has been examined by Mr. Teall, who describes it as composed of "large quartz and felspar grains in a fine schistose matrix. The grains of quartz and felspar (oligoclase) are often much crushed and granulitized. The matrix is a fine-grained aggregate of chlorite, sericite and quartz, with some iron ores and leucoxene (?)." The rock is "markedly less crystalline than some chloritic and epidotic grits from the north of Ben Ledi," which were examined at the same time.

The green grits have been traced continuously from the Balquhidder district to Loch Katrine, and also mapped in an outlier on the western side of Loch Lubnaig. They show very little change in character in this area, though it has been noted that fine schistose chloritic beds are more numerous in the south-western part, where they replace, to a certain extent, the coarser epidotic grits, which are well seen near Loch Lubnaig, especially in the upper part of the group. Small ill-defined yellowish green knots or nodules, and strings or folia of similar material are sometimes observed, while thin veins or bands of massive chlorite occur more rarely.

Mr. Teall has examined several specimens from the ground north of Ben Ledi, and the following descriptions are taken from his notes: "(8227). Irregular grains of quartz and plagioclase in a matrix of sericitic mica, chlorite, epidote, and some turbid indeterminable material." In a coarser grit (8228), "the quartz-grains often show peripheral granulation, and thus tend to merge themselves in the crystalline matrix." A still coarser grit contains large grains of quartz and plagioclase: (8229). "The large felspars, one of which gave the reaction of oligoclase in the flame, are more or less granulitized." (8230) is "a dark fine-grained rock, traversed by thin yellowish-green bands or folia of

Strathyre and the Crossachs. (Mr. Cunningham-Craig.)

epidosite. The fine-grained bands are an aggregate of epidote, chlorite, white mica, granulitic quartz, and felspar, with sphene as an accessory. The light yellowish-green bands are formed of epidote, quartz, and a few large flakes of biotite." MR. TEALL describes these crystalline epidotic grits as similar to rocks which he has examined from the Cowal district, and he notes that "the clastic character of the rocks is very obvious in the coarser-grained specimens, but becomes much less so in those which are finer-grained, and finally ceases to be recognisable."

Small intrusions of felstone and lamprophyre have been observed occasionally in this area; the lamprophyres increase in number in Glen Gyle, while felstones are more numerous about the eastern end of Loch Katrine and in Glen Finglas. Dolerite dykes are rare, but can occasionally be traced for great distances.

The mapping of the "Green Beds" north of Loch Katrine has revealed a remarkable change in the character of the folding, and has made clear the structure of the district. A large trough has been traced from the Balquhidder area, where the folding is simple and undulating, to Loch Katrine. This trough brings in the epidiorites, a sill of which is exposed in the centre of the trough on the watershed between Glen Dubh and Glen Finglas. In the south-western part of the area the eastern limb of the syncline is found to be inverted, while the dips become steeper and the folds more closely packed, till finally, on the shores of Loch Katrine, east of Brenachoil Lodge, the folding becomes vertical and isoclinal. The structure in the eastern part of this area is further complicated by a series of north-east and south-west faults, which, in conjunction with the steeper folding have the effect of repeating the outcrop of the Green Beds three times in the burn-section in Glen Finglas.

The Glen Ample fault, with several subsidiary dislocations, has been traced for three miles on the western side of Loch Lubnaig, the slate-bands showing very clearly the effect of each dislocation. There appears to have been some horizontal movement along this line of discontinuity, as shown by slickensides, and the apparent dragging of nearly vertical slate-bands on the eastern or upthrow side, horizontally into the line of fault.

Argyllshire.

Loch Awe and Glen Etive. (Mr. Kynaston.)

In Argyllshire considerable tracts of the younger or Dalradian schistose rocks have been mapped during the past year. MR. HILL, as already mentioned, returned for a short time to his former ground in the Loch Awe district, but met with no new features of sufficient importance to require mention here. Further to the north small tracts of the same rocks were mapped by MR. KYNASTON, but except with regard to the phenomena of contact metamorphism, which will be fully considered in a later section of this *Summary* (p. 82), he encountered no new facts of note. He found the Loch Awe and Ardrishaig series to maintain their normal and characteristic features in

the tract between Dalmally and the Cladich Burn, and as on the opposite side of Loch Awe, to appear frequently in a very unaltered condition. They include numerous hornblendic sills which show considerable petrological variation. Small sills are also occasionally met with consisting mostly of fine-grained more acid rocks, sometimes porphyritic. These, MR. KYNASTON believes, belong to the great series of porphyrite dykes and sills associated with the Ben Cruachan granite. Loch Awe and Glen Etive. (Mr. Kynaston.)

In the Glen Etive district the same observer has again had occasion to map some of the younger schists while working a part of the ground to the west and north-west of the Glen Etive granite, lying between Glen Etive and the upper portions of Glen Creran and Glen Ure. Here, however, the condition of the schists is in marked contrast with those of Loch Awe side. They show altogether a much greater degree of crystallisation and schistosity, which does not become appreciably lessened as they are traced away from the granite. Evidently they had been much more affected by the forces of the so-called dynamo-metamorphism, which, as it were, left their imprint upon them previously to the intrusion of the Glen Etive and other newer granites. The fact is here again exemplified that earth-stresses which determined the structure of the ground have acted with increasing intensity from the more south-western portions of Argyllshire in a general north-easterly direction.

The schists to the west of Glen Etive may be divided provisionally into the following groups:

(1). *Massive white quartzites.* A white or greyish tough quartzite, sometimes pinkish, and often slightly banded or laminated. This group is especially well developed on the northern and southern flanks of Beinn Fhionnlaidh, and in Allt Charnan. It is also occasionally met with as inclusions in the granite. The quartzites are succeeded by

(2). *Quartzose and biotite-schists,* well exposed on the southern slopes of Beinn Fhionnlaidh, and other places. Here may also be included some pinkish gneissose micaceous schists (with two micas), which succeed the quartzose and biotite-schists, and are well developed in the upper portions of Allt nan Gaoirean. These rocks undergo the hornfels type of alteration along the granite margin. Next to these by gradual passage, come

(3). *Garnetiferous mica-schists,* — pale silvery-grey, markedly foliated rocks, well-developed at the head of Glen Creran, and in the corries at the head of Allt Charnan.

All these sedimentary materials are frequently found to be traversed by sills of porphyrite, as was also so frequently found to be the case in the districts bordering the Ben Cruachan granite further to the south west. The older hornblendic (epidiorite) sills are, however, rare in the Glen Etive area.

A more detailed description of some of the schists just enumerated will be given in a later Section of this *Summary,* devoted to the contact metamorphic phenomena around the great granite masses of Ben Cruachan and Glen Etive (p. 76, *seq.*).

trict of h Eil and t William. r. Grant-lson.)

In the districts bounding the head of the Linnhe Loch, MR. GRANT-WILSON has extended his previous survey on the west side by mapping the ground as far south as Glen Scaddle, and as far north as Gairlochy, while on the east side he has examined the lower part of the Great Glen, and the hills on the south side of the lower or western end of Glen Nevis. The important dislocation which runs along the line of the Great Glen passes through the middle of his area.

In the basin of Loch Eil the "gneissose flagstones," referred to in last *Summary*, continue across the district surveyed last year, dipping S.E. and S.S.E. at an average angle of between 20° and 30°, though to the west of Fassafern they become more contorted. Similar rocks extend northwards beyond Glen Loy, but dip there to S. and S.W. Between that glen and Loch Lochy they are intersected by numerous dykes and veins of pink granite.

Some large and hitherto unrecorded masses of intrusive rock have been met with piercing the flagstones. One of these, which has not yet been completely traced out, forms an irregular oval, three miles long by two and a half broad, stretching across Glen Scaddle and is seen in section in the river Scaddle. As far as yet examined, it consists of a core of epidiorite with an outer margin of a more acid material, all more or less foliated. In texture the epidiorite varies from coarse to medium, and it is generally of a dark grey colour. A specimen taken from the river Scaddle, half a mile below Creag Bheitheachain, has been sliced and examined by MR. TEALL, who reports as follows regarding it:—

"[8233.] Medium-grained rock composed of colourless plagioclase and a dark green mineral. Under the microscope it is seen to be essentially composed of basic plagioclase and fibrous or uralitic hornblende. Chlorite and iron-ores are also present. The plagioclase floats in the diffusion in a dense zone slightly above labradorite and well below oligoclase. It belongs to the labradorite-andesine series. This rock has the structure and composition of epidiorite."

A large number of hill streams fall into the river Scaddle and these, with the fine cliffs of Creag Bheitheachain and Choire Bhulg afford numerous exposures of this rock. From a number of observations the general direction of the foliation in this epidiorite was found to vary from 15° to 25° west of north.

Near the foot of the glen at the Eas Dubh fall, and at its western boundary on the slopes of the Druim Leathad nam Fias, this epidiorite is surrounded by a zone of granulitic gneiss from 150 to 300 yards in breadth, which appears to be wholly or in part composed of foliated igneous materials. At the falls where a good section is exposed the relation of this gneiss to the epidiorite on the one side and the flagstones on the other is clearly seen. The junction with the epidiorite is a vertical wall, and a similar boundary may be seen also at the western edge of the epidiorite above Creag Bheitheachain. As the falls are approached from the east the flagstones are observed to become more baked and twisted, until from the foot of the falls for 130 yards they are traversed by intrusive dykes of this acid gneiss, which in many cases cross their lamination at a slightly oblique

angle. Above the falls a belt of light brown, fine-grained gneiss 70 yards broad contains numerous included fragments of gneissose flagstone, which vary in size from a few cubic inches up to several cubic feet. The inference that the gneiss is of igneous origin is strengthened by the microscopic examination of a specimen from this locality, examined by MR. TEALL, who has supplied the following description of it:— District of Loch Eil and Fort William (Mr. Grant-Wilson.)

"[8,235] A light coloured, banded, granulitic gneiss. Under the microscope it shows turbid plagioclase felspar, fresh microcline and quartz (very abundant). The quartz and microcline form a foliated aggregate in which the turbid felspar occurs as phenocrysts without crystalline form. Biotite and sphene occur as unimportant accessories."

In the river Scaddle above and below Creag Bheitheachain the epidiorite is cut by dykes of basic rock with zoned plagioclase-felspar crystals. These dykes are even more foliated than the surrounding rock and now form hornblende-biotite schists. A fine grained specimen of the massive dyke below the cot house of the "Creag" is described by MR. TEALL as:—

"[8,236] Fine-grained dark-grey foliated granulitic rock. Under the microscope it shows a foliated aggregate of plagioclase, biotite and hornblende, with some quartz, sphene, and iron-ores, as accessories. Viewed with ordinary light the rock appears to be an ordinary hornblende-biotite-schist, but under crossed nicols the plagioclase is seen to be zoned. The central core extinguishes at a different angle from the periphery. There is moreover a tendency to the lath-shaped form. This peculiar structure differentiates the rock from the normal schists, and I am inclined to regard it as igneous."

The epidiorite, the zone of granulitic gneiss, and the hornblende biotite-dykes are alike traversed by numerous dykes and veins of porphyrite, which, however, are most numerous, within the epidiorite area. They are all more or less foliated, and where included within the epidiorite they are always more foliated than the surrounding rock. These aplite dykes are generally light in colour, contrasting strongly with the darker epidiorite. A specimen taken from one, four yards broad, cutting the epidiorite in the River Scaddle half a mile below Creag Bheitheachan, is thus described by MR. TEALL:

"[8,234.] A light-coloured, medium-grained porphyritic rock. Examined with the microscope it shows phenocrysts of zoned plagioclase (in part oligoclase) in a matrix of micro-crystalline quartz and alkali felspar. The outer zone of the phenocrysts belongs to the same period of consolidation as the ground-mass. Ferro-magnesian minerals are very scarce and are represented by biotite, often replaced by chlorite. Sphene occurs as an accessory. The rock may be termed a porphyrite."

From MR. TEALL'S description of the igneous granulitic gneiss and porphyrite dykes of Glen Scaddle, it will be seen that they bear a close resemblance to one another, so far as composition is concerned.

To the south of Glen Scaddle, and on the steep craggy slopes of Beinn na Cille, that stretch downwards to Loch Linnhe, several foliated diorite dykes traverse the flagstones of this hill. In all probability they emanate from the Glen Scaddle igneous mass.

Since all these igneous rocks here described as part of the Glen Scaddle network are foliated in a direction common with the

strict of ch Eil and rt William. r. Grant- lson.)

general foliation of the surrounding rocks, it is evident that they have all been intruded prior to, or during, the movements which produced the foliation of the district. Partly for this reason, and partly on account of their petrological relationship, the various intrusions which cut the epidiorite may be considered not improbably to mark successive injections from the same original magma, which gradually became more and more acid as its more basic constituents separated out.

Another important mass of somewhat basic material, having an intrusive origin, lies directly to the north of the Banavie granite mass, and has been traced for a distance of three miles up Glen Loy. Its outline is very irregular, but its average breadth north and south of the river Loy is about one mile. As shown in the excellent section cut by the river, the rock in general consists of a medium-grained steel-grey diorite with lath-shaped and prismatic hornblende crystals, but in some places, as in the main stream below Inverskilavulin, becomes much coarser and includes large bladed crystals of hornblende. An average specimen of this rock taken from where the north Dubh Chlaise joins the river Loy was analysed by MR. GRANT WILSON, and gave the following result:—

SiO_2	43·84
TiO_2	·27
Al_2O_3	24·64
Fe_2O_3	3·97
FeO	6·73
MnO	·29
CaO	10·24
MgO	4·95
K_2O	·99
Na_2O	2·58
Loss on Ignition	1·83
	100·33

From the chemical composition thus exhibited the rock is therefore a gabbro-diorite. A specimen similar to that analysed was taken from the river 200 yards above the bridge of Loy, and sliced for microscopical examination by MR. TEALL, who reports regarding it—

"[8289.] Under the microscope, hornblende, biotite, plagioclase, iron ores including pyrite and apatite. Epidote and chlorite as secondary products.—The rock is a diorite."

At the Tom an Eildean ridge, the edge of the diorite is very coarse, some of the crystals of hornblende measuring over two inches in length. MR. TEALL describes the rock as follows:

"[8290.] Extremely coarse-grained aggregate of hornblende and plagioclase (1—2 cms.). The rock is a diorite-pegmatite. Under the microscope, plagioclase, hornblende, and a little biotite, with some secondary chlorite."

Below the bridge of Loy the fine-grained edge of the diorite mass is seen in contact with baked micaceous schist, both being cut by thin red granite veins. On the north side of Gley Loy

also the junction between the diorite and the granulitic flagstones is well exposed both on the driftless hill-slopes and in the numerous streams that flow down their sides. For some distance outward from the contact, the flagstones are baked and altered and become gneissose. District of Loch Eil and Fort William (Mr. Grant Wilson.)

The Coire an Light uinn Burn crosses the boundary line of the diorite several times. The banded flagstones are broken and indurated, and together with the igneous rock are cut by numerous small red granite dykes.

A description of the Banavie granite was given in the *Summary of Progress* for 1897. A sample of this rock from the Strone quarry has since been analysed by MR. GRANT-WILSON, with the following results.:—

SiO_2	76·71
Al_2O_3	11·68
Fe_2O_3	1·01
FeO	1·5
MnO	·09
CaO	·44
MgO	·16
K_2O	6·65
Na_2O	·80
Loss on ignition	·61
	99·65

This granite about twenty years ago was worked to a considerable extent at the Strone quarry. A specimen of it sent to MR. TEALL was examined by him microscopically and he describes it as:

"[8291]. Pink, medium-grained granite with a few flakes of biotite. Under the microscope oligoclase, microcline (very abundant), quartz and biotite (very scarce). The rock is a microcline-granite."

The main mass of Banavie granite bounds the Glen Loy diorite on its south side. The junction line between the two rocks is very irregular, and the granite sends great tongues into the more basic mass. Beyond the contact boundary the diorite is traversed by numerous dykes of granite.

Above the Bridge of Loy several large and small pink granite dykes cut the diorite with a general north-east course. From one of these, 300 yards above the bridge, a specimen was submitted to MR. TEALL, who reports regarding it:

"[8292.] Medium-grained pink granitic rock, almost entirely composed of quartz and felspar. Under the microscope microcline, quartz, and biotite (scarce). The rock contains a little vermicular pegmatite. There may be a little original muscovite. It is a microcline-granite."

For about a mile-and-a-half above the Bridge of Loy these pink granite dykes are very numerous. The acid material sometimes takes the form of sills. The diorite is here also intersected by numerous veins of pegmatite, lighter in colour than the material of the granite dykes, much coarser in texture, and often presenting badly defined irregular margins. A specimen from

District of Loch Eil and Fort William. (Mr. Grant-Wilson.)

one of these pegmatite veins from the foot of the Allt Barraich, Glen Loy, examined by MR. TEALL, is thus described by him:

"[8293]. A nearly white rock, containing small scales of muscovite. Under the microscope appear oligoclase, alkali-felspar, including microcline, quartz, and muscovite, magnetite as an accessory. Alkali-felspar, quartz, and muscovite often occur in large plates, showing micro-porphyritic structure and quartz and alkali-felspar sometimes show micropegmatitic structure—the rock is a muscovite-granite."

The close resemblance of the determinations by MR. TEALL of the Banavie granite, the pink granite dykes, and the pegmatite-veins cutting the diorite, together with the direct evidence afforded by the Glen Loy sections, show the granite to be of later origin than the more basic rock, and indicate that the granite dykes are apophyses from the main mass. The Banavie granite, the Glen Loy diorite, and its granite-dykes are all unfoliated.

An interesting feature of the ground surveyed by MR. GRANT-WILSON last year is the occurrence of dykes of the Scourie type in the flagstones on the ridge of the Coille Mhor of Fassafern. One of them, 18 yards broad, which has an easterly course, and stands out in bold relief above the surrounding flagstones, is hard and tough, dark-grey—almost black—in colour, and studded with rough aggregates of hornblende, some of which are more than a quarter of an inch in length. A specimen of this rock, examined by MR. TEALL, is thus described by him:—

"[8199]. Under the microscope green hornblende in large ragged poikilitic patches and aggregates of smaller individuals, granulitic plagioclase, iron-ores, and sphene. Original structures obliterated. This dyke is of the Scourie type—epidiorite."

These dykes appear to be earlier in age than the other varieties that traverse the flagstones. They may be related to the Glen Scaddle mass. Several other hornblende-schist sills (some with garnets) were mapped in the flagstone area. These probably belong to the same period, with the dykes just referred to. In addition to the numerous red granite-dykes, several red and grey felspar-porphyries are seen in the Annet Burn, and also along the ridge of the Druim Fada.

East of the line of the great fault that coincides with the chain of lakes and the long hollow of Glen Albyn, MR. GRANT-WILSON continued the mapping of the zones of schist traced by him between Fort William and Loch Leven, and followed them northwards across the tract between the Ben Nevis mountain group and the rivers Spean and Lochy. These zones consist of (1) Sericitic mica-schist, (2) Black schist, (3) Dark-grey flaggy mica-schist, (4) Limestone, and (5) Black Schist.

(1.) The most westerly portion of the strip of sericitic mica-schist near Camisky is generally green in colour and garnetiferous, and includes deformed strings and masses of black-schist and quartz-schist. In the continuation of this zone to the south of Fort William, the best examples of the rock are to be found

along the Auchintore shore, a specimen from which is thus described by MR. TEALL: District of Loch Eil and Fort William (Mr. Grant-Wilson.)

"[6241.] A fine-grained greenish-grey schistose rock. Under the microscope, quartz, felspar (partly striated), sericite and chlorite; iron ores and a carbonate as accessories. Some of the large grains of quartz and felspar appear to be clastic fragments. I think the rock is a sheared fine-grained grit."

The streams and craggy ridges above Auchindaull, about two miles S.W. from Spean Bridge, give good exposures of this crumpled and contorted schist, but the best section in the district is to be found in the rock gorge of the River Spean above Gairlochy, which is not yet completely surveyed.

(2.) A belt of black schist varying in breadth from 150 to 400 yards lies between the sericite-schist, just mentioned, and the flaggy mica-schist. At a distance of 300 yards from the edge of the Ben Nevis granite this belt is exposed in the stream above the Ben Nevis distillery, where the rock is metamorphosed by the granite into a dark-grey banded hornfels. Traced to the north, away from the intrusive mass, the rock becomes less altered. At the back of New Inverlochy Castle it is still permeated with small dykes of granite, while below Auchindaull it contains knots and garnets.

(3.) The River Spean, between the Free Church of Killmonivaig and Roy Bridge affords an admirable section of the zone of dark-grey flaggy mica-schists. Owing to deep drift between the Spean and Fort William, only isolated rock sections are exposed in that part of the district. Along the course of the River Lundy, which runs at no great distance from the margin of the granite, these mica-schists are seen to be much altered. They have been converted into hornfels.

(4.) The band of limestone is an extension of that which has been traced in a continuous line (except where intersected by Loch Leven and the Appin Ferry) from the south point of Lismore to Glen Nevis. In the tract between Fort William and the Spean it extends from Creag Aoile to Lianachan, and a traverse of the ground showed it to be continuous into Glen Roy, whence it probably stretches much farther to the north-east. It is well exposed at the Creag Aoile, where it appears as the purest crystalline limestone that has yet been met with during the Geological Survey of the Argyllshire Highlands. Almost entirely free from any admixture of black-schist, it is generally light grey in colour, with white bands. It more closely resembles the Appin limestone than that of Lismore. The planes of foliation in it are inclined at a high angle to the north, and its apparent breadth at the surface may to a certain extent be due to folding. To the south-west of Creag Aoile the limestone abuts directly against the granite, but probably on account of the purity of the rock, the contact minerals appear to be absent.

(5.) Of the second zone of black schist only a portion has yet been mapped. In the east Allt-Criche Burn a band of grey slaty phyllite comes next to the limestone. It is succeeded by a small belt of limestone, after which the black schist sets in,

trict of
h Eil and
t William.
r. Grant-
lson).

regularly foliated, and dipping to the south-east. This schist is cut by several dykes of granite, felspar-porphry, and lamprophyre, and passes into the condition of flinty hornfels.

Besides mapping the triangular space between Ben Nevis, the Spean, and the Lochy, MR. GRANT-WILSON was able to devote some time to ground situated to the south-west of Ben Nevis, in continuation of his previous survey of the district lying further to the south. He had already traced the northern limb of a synclinal fold of the limestone which stretches north-eastward from Corry Churachan, two miles north of Corran Ferry, to Beinn Riabach, two miles south of Fort William. Round this last-named hill the limestone forms steep crags, which overlook Glen Nevis, and folding upon itself it then turns round to the south-west, passing through Blarmachfoldach to the water of Kiachnish. In this district it is thrown into three synclinal folds, the centres of which are occupied by black schists. From the Coire a Mhuilinn, where the limestone passes below the black schist by the base of Sgor Chalum to the River Nevis, the rock presents an almost continuous outcrop. In Glen Nevis, at the surface, it is only separated from the granite of that glen by a narrow terrace of alluvium. To the west of the Water of Kiachnish, on both sides of the synclinal fold, the rock appears as an ordinary crystalline limestone. At Blarmachfoldach, two and a half miles from the Ben Nevis granite, small crystals of actinolite first show themselves in a band of impure limestone. Nearer to the granite, as was stated in the last *Summary*, the limestone is still further altered, and a specimen taken from the crags above Glen Nevis House was found by MR. TEALL to be "a light grey hornfels, containing some large crystals of hornblende."

The limestone is succeeded to the south-east by a considerable area of black schist, of which good sections may be seen in the water of Kiachnish, in the Coire a Mhuilinn, and on the rocky slopes of Sgor Chalum. In these exposures the strata have a north-east and south-west strike, and are generally either vertical or inclined at a high angle to the south-east. They consist mainly of black schist with occasional bands of phyllite. To the east of Lundavra these rocks pass latterly into the grey and green phyllites with black schist partings, which have already been mapped to the shores of Loch Leven, around North Ballachulish. The north-eastern corner of this area of black schist abuts against the Ben Nevis granite, while its south-western margin surrounds the granite boss of Meall a Chaoruinn. The contact metamorphism around these two igneous masses is very remarkable.

In the stream-sections midway between these two granites, the black schist is little altered, though the various dykes which intersect it are there numerous. In the course of the Kiachnish Water the rocks become more altered as they approach the granite of Meall a Chaoruinn. Some of the bands become knotted schists, while others are filled with small garnets. A specimen taken from the river below Blar a Chaoruinn, about

400 yards from the edge of the granite is thus described by MR. TEALL: District of Loch Eil and Fort William (Mr. Grant-Wilson.)

"[8277.] A dark grey banded rock. Under the microscope it presents a confused aggregate of nearly colourless mica and micro-crystalline quartz, together with biotite, andalusite, and opaque grains, which appear white by reflected light (leucoxene)."

A similar progressive metamorphism is also to be seen as the black schist approaches the Ben Nevis granite. To the south-east of the vitrified fort, the schist becomes a dark, massive, well-banded steel-grey rock, which is hard to break. On the surfaces of the foliation planes mica is assembled in spots and masses. A specimen submitted to MR. TEALL was found to be:

"[8278.] Mainly composed of biotite and quartz. The biotite occurs in extremely small scales, and also in large irregular plates with pleochroic halos. There is also sericitic mica, chlorite, pyrite, and a few small crystals of tourmaline.—Biotite Schist."

The western edge of the Ben Nevis granite mass has now been traced from a point near Glen Nevis House north-eastward to the Sgor a Pheanais, a distance of six miles. It coincides generally with the line along which the different hills and ridges that form the mountain mass of Ben Nevis sink into the plain. Half a mile above Glen Nevis House the intrusive character of this granite is well seen in horizontal sections in the rocky bed of the river. The flaggy mica-schists are there intensely altered and shattered. The granite is steel-grey in colour, with flecks of black mica, but weathers rusty-red. So far as it has been mapped the rock is all unfoliated. It is medium in grain, but towards its edge it becomes fine-grained. A specimen taken from the hill above this section is thus described by MR. TEALL:

"[6561.] Medium-grained, grey granite. Under the microscope zoned plagioclase, orthoclase, quartz, biotite, and green hornblende are seen. Brown sphene, iron-ores (scarce), and apatite as accessories. Pleochroic halos round indeterminable inclusions in biotite. The felspars and quartz all lie between sp. gr. 2·65 and 2·56. The zoned plagioclase probably ranges in composition from andesine or possibly labradorite to oligoclase, and agrees on the average with a somewhat basic oligoclase. It is markedly idiomorphic, and is the dominating felspar. Quartz and orthoclase occur as interstitial matter. The margins of some of the plagioclase crystals contain vermicular quartz. Hornblende is pale-green in colour, and not very abundant. The granite is closely allied both in structure and composition to the granites of the Galloway region. The rock is a biotite-granite with some hornblende."

Another granite mass forms Meall a Chaoruinn (2,941 feet), which rises three miles south-west from the western edge of the Ben Nevis granite, and near the head waters of Kiachnish Water. This height, with its red screes standing out in bold relief against the white quartzite ridge of Stob Ban, forms a conspicuous feature in the landscape. The rock, which is everywhere unfoliated, is pink in colour, and varies from a medium to a coarse grain. It is largely composed of quartz and alkali-felspar, and contains a few flakes of muscovite. Examined by MR. TEALL, it was found to consist of "[8276] Oligoclase, alkali-felspar (micro-perthite), and quartz. The rock is mainly

composed of alkali-felspar and quartz. It is almost a binary granite. The quartz contains liquid inclusions, with moving bubbles." He adds that this is the most acid granite that has as yet been obtained from this series of eruptive rocks. The outline of the mass forms an irregular square, with rounded corners, embracing about a square mile and a half.

In Glen Seileach, about two miles further to the south-west, the schists are pierced by a small boss of pink granite, which thus lies midway between the granite masses of Meall a Chaoruinn and Ballachulish. This rock, which is very much weathered, appears to be identical in composition with that of Meall a Chaoruinn. It has been examined by MR. TEALL, who thus describes it:

"[6562]. Pink in colour, and medium-grained, with earthy pale-green decomposition products, after a ferro-magnesian mineral. Under the microscope it is too much altered for satisfactory determination. Idiomorphic plagioclase (highly altered), very abundant, interstitial quartz, chlorite, secondary white mica, &c.—altered biotite-granite."

A considerable number of lamprophyre dykes and sills traverse the black schist and limestone between the top of the Bidean Bad na h'Iolaire and the shoulder of Sgor Chalum. In some places they are so numerous that as many as 27 have been mapped in a single mile of section in the Coire a Mhuilinn. As a rule, they are comparatively narrow, and cannot be traced far. Their general trend is towards E. 30°–40° N. One large example has been traced from the Kiachnish Water to Blarnacdrynie, a distance of a mile and a half.

Camptonite dykes and sills, which are varieties of the lamprophyres, are closely associated with these. They are found chiefly on the south side of the "Beiders," and on the shoulder of Sgor Chalum. The course of some of these can be traced for more than a mile, and their direction varies from E. 30° N. to E. 45° N., with a breadth of from 10 to 20 feet. A specimen collected to the south of Blar nan Cleireach is described by MR. TEALL as follows:

"[6559]. Dark, almost black medium-grained rock. Under the microscope acicular prisms of brown hornblende and plates of greenish-brown biotite, in a matrix of felspar, which is in part, if not wholly, plagioclase; apatite fairly abundant as an accessory; iron-ores very scarce. The felspar of the matrix occurs in large irregular individuals in which the ferromagnesian minerals occur as inclusions, thus giving the rock a marked micro-poikilitic structure—diorite (camptonite)."

Dykes of porphyrite are less common than those of lamprophyre and camptonite. Their general direction is N. 45° E. In two instances they have been observed to cut lamprophyre dykes. Above the old military road at the Allt Riasgaig, a dark green dyke cuts the black schist and limestone. Embedded in the base are large white porphyritic crystals of felspar, often measuring a quarter of an inch in length, and giving the rock a striking appearance. An examination of this rock by MR. TEALL showed:—

"[6560]. Phenocrysts of more or less turbid plagioclase and altered biotite in a micro- or crypto-crystalline matrix; carbonates fairly abundant; they form pseudomorphs after phenocrysts of some ferro-magnesian mineral, probably augite. The rock is a porphyrite."

District of Loch Eil and Fort William (Mr. Grant Wilson.)

MR. GRANT-WILSON'S field-work last year has afforded still more direct evidence as to the exact position of the powerful fault which runs along the line of the Great Glen. Below Torcastle the river Lochy runs over a succession of rocky cascades, caused by bands of silvery mica-schist which belong to the series of rocks on the east side of the dislocation. At a distance of 320 yards to the north-west of this river-section gneissose flagstones are seen above the public road, so that the fault must pass between these two points. In the Moyburn, at the road-bridge, and for some distance up stream, the flagstones are so broken up, twisted, and veined with calcite as to be hardly recognisable. From their shattered condition it may be inferred that if this is not its actual position, the line of fracture cannot lie far off.

Oban District. (Mr. Symes)

From Oban as a centre, MR. SYMES has continued his field-work, in the course of which he has had occasion to map some further small portion of the Argyllshire schists. He finds these rocks well developed about Kilmelfort. On the shore there they consist of phyllites and mica-schists, which, further to the east, are replaced by one thick band of limestone, followed by thin siliceous schists, then by epidote-chloritic biotite-schists, and lastly by siliceous schists, with occasional thick quartzites. The whole section shows a steady dip to the east; but little crumpling or repetition of the beds has been detected. The one zone of limestone which may be about 30 feet thick, but is composed of numerous beds, is not repeated as far as the survey has yet advanced. Throughout the section numerous intrusions of epidiorite were noticed in all the beds. The eruptive rock shows considerable variation, but for the most part it is of the usual dark-green hornblendic type, both compact and schistose, and very decomposed. At the waterfall on the Gleann Mor River, N.E. of Kilmelfort, bedded epidiorites occur unlike any others in the district. They are light grey in colour, and have needle-shaped crystals of felspar, as well as milk-white specks of felspar and crystals of iron pyrites in a very compact light grey matrix. These rocks occur in thick beds without any shearing, whereas the hornblendic epidiorites nearly always show signs of schistosity. The section at Kilmelfort presents a remarkable resemblance to that at Campbelltown in Kintyre, the succession of the beds being the same; but the beds at Campbelltown are much folded and form an anticline, while those at Kilmelfort have a steady dip to the east. If this inclination can be taken to indicate the general succession of strata the Kilmelfort beds would appear to lie on a much higher horizon than the black slates and associated limestone which occur at Easdale, Kerrera Island, and as far north in this district as Loch Creran.

For economic purposes the limestones at Kilmelfort are valuable for their marked binding properties, but they can hardly compete in a financial point of view with the richer limestones of the Carboniferous and other formations which can be brought to these coasts by sea.

In the Balvicar and other quarries about Easdale numerous

Oban District. (Mr. Symes.)

bands of limestone have been noted among the slates and sometimes also nodules of limestone. The slates in the Balvicar quarry are classed as blue and black; the former include large cubes of iron pyrites which are not detrimental to their sale. Both blue and black are of about the same general value in the market.

Slates were once worked at Ardentallan, on the north side of Loch Feochan, but the quarrying of them had to be abandoned owing to local encroachment of the sea.

(Director-General.)

"Good sections to illustrate the relations between cleavage and bedding are to be seen along the shores of Seil Island. Thus, on the bend just east of Easdale school-house, the Dalradian rocks, inclined at 74° to E.S.E., consist of black slates or phyllites with intercalated beds of limestone. The slates are traversed by a cleavage which dips in the same direction at 50°. They are also finely frilled or puckered, and the cleavage-planes are covered with a silvery sericitic surface. Here foliation has taken place along the planes of cleavage. The limestones are earthy, shaly, and compact, and, like the slates, are full of cubes of pyrites.

"A few yards to the south of the part of the beach where these observations were made the strata rise in the opposite direction, but the cleavage still continues towards S.E., though with less regularity, and its planes are occasionally curved. The slates vary here not only in the direction but also in the amount of their inclination, the dip being sometimes as low as 15° and changing in a few yards to verticality."*

A large mass of diorite has been mapped east of Balvicar; the exposure extends S.W. for about two miles, its greatest breadth being about half-a-mile. Beds of dolomite with a large percentage of iron occur in it along cleavage-planes.

Island of Jura. (Mr. Wilkinson.)

The survey of Jura by MR. WILKINSON, during the past year, has not disclosed any new facts of importance in the geology of the island. The quartzites along their south-eastern boundary have been found sometimes to contain so much dark material, like that of the adjacent graphite schists, as to take a dark blue or black tint throughout the quartzite area. The beds are often gritty and pebbly, and along their eastern margin they appear to have been subjected to much movement. In a north-westerly direction across their strike they become more massive, and vary from fine to coarse conglomerates. The pebbles in these strata are quartz and quartzite, and a few of jasper were noticed. The more massive beds appear to be separated by occasional bands of cleaved quartzose shale, and dip steadily in a south-easterly direction at angles of from 30° to 40°. So even and uniform is their inclination that at some little distance no sign can be detected that the beds are repeated by folding. Anyone sailing round the coast, particularly on the north-western side of the island, cannot but be struck with this apparent persistent uniformity of dip. On closer examination, however,

* Notes by the Director-General made during an inspection of MR. SYMES' ground in the summer of 1898.

ample evidence is found that the strata have been repeated by a system of V-shaped folds. By this structure an appearance of enormous thickness has been given to this formation, which is probably entirely deceptive. So far no annelid tubes have been discovered in the area surveyed. The Director-General, however, found some on the west side of the island in the district over which the mapping has not yet extended. Island of Jura. (Mr. Wilkinson.)

Like the quartzites, the slates and schists of Jura exactly resemble those of the east coast of Islay, of which they are doubtless a prolongation. They probably represent the calc-sericite schists and quartzose grits of the Ardrishaig series of the mainland. Occupying a band or strip of land about two miles wide on the south-east shores of the island, they extend in a north-easterly direction along the coast as far north as the field-work has yet reached. They appear and disappear with the folds of the quartzite. Where the latter rock comes in contact with the schists it is exceedingly difficult, if not impossible, to separate the sheared quartzite from the quartz-schists of the schist series. In the quartzite area between Lowlandman's Bay and Tarbert several inlying areas of slates and graphitic schist have been met with. At Tarbert Bay, where the slates have been extensively quarried a good rough slate has been obtained, but owing to the frequent occurrence of gritty bands, so large a proportion of the rock is useless, that quarrying does not repay the cost of labour and carriage. The same remark also applies to the quarries which were opened at Inverlussa, but which have been closed for some time. The same double set of planes of movement can be traced in the schists and slates which has been noticed in the cleaved beds in the quartzite. A good example of the structure may be seen a little south of the Forest Lodge. In this group a few bands of dolomitic limestone have been observed, which generally weather with a characteristic honeycombed surface.

Between Ardfin and Ardmenish the group of schists includes intercalated sills of epidiorite. These eruptive rocks occur in massive sheets, and form dark jagged ridges along the coastline and for some little distance inland. They occur in exactly the same manner as those of Islay. The centre of each sill is generally a coarsely porphyritic rock, which would make a handsome ornamental stone if polished, as it contains large crystals of a pale flesh-coloured felspar scattered through a mottled greenish matrix. Towards the edges, the texture of the rock becomes much finer and closer, more schistose, and generally of a darker green colour. Although the ridges formed by these rocks are so numerous as to convey the impression that many sheets of igneous material have been injected into the sediments, it is probable that the appearance is deceptive, and that in reality there are only a few sills which have been repeated over and over again by a system of plication. The axes of the folds run parallel to each other in a north-easterly and south-westerly direction. Epidiorite sills do not occur in the main mass of the quartzite.

North of Loch Tarbert the epidiorite ceases to occur in the form of sills. On the other hand, a number of fine-grained dark

Island of Jura. (Mr. Wilkinson.)

green dykes of that rock form well-marked features as they traverse the quartzite. They run for miles, some from east to west, others from north to south, and often cut one another at right angles. One of them near Ardlussa stretches completely across the island and runs parallel to and not far from a dyke of olivine-dolerite, both of the dykes forming prominent ribs of rock.

It is worthy of note that where these dykes of epidiorite make their appearance no sills of that material are to be seen, while at the same time the ordinary olivine-dolerite dykes of the north-west or Tertiary series become much less numerous. The age of these exceptional epidiorite dykes remains to be determined. In spite of their coincidence in direction with the later dykes of the West Highlands they are probably vastly older than these. They have not yet been studied petrographically, but they are provisionally placed with the epidiorite sills. A more minute study of their internal composition and structure may throw some light on their place in the succession of the rocks of the island.

One further variety of eruptive material may be noticed here in connection with the Dalradian rocks of Jura. It is a red porphyry which occurs as sills in the quartzite north of Loch Tarbert. Its petrographical characters remain to be investigated.

Island of Arran.

(Mr. Gunn.)

The last district to be noticed in which the field-work of 1898 included any portion of the Dalradian rocks of the Highlands is the island of Arran, where during the greater part of the working season MR. GUNN continued his survey. As is well-known, the central granite of the northern half of the island is surrounded with a nearly continuous ring of schists. MR. GUNN in mapping these rocks has found that the term mica-schists under which they have frequently been referred to, is hardly applicable to them as a whole, seeing that mica is sparingly developed in them, except in the finer grained varieties, such as appear on the shore about Imachar, Pirnmill, and Thundergay. Along these parts of the coast, however, the rocks have been more than usually plicated and contain numerous quartz-veins. Generally the rock is a moderately fine-grained schistose sandstone, including occasional bands of a fine blue slate, and also rocks of a decidedly gritty character, schistose greywacke, and conglomerate with deformed pebbles. The coarsest bands are thin, and cannot be traced far. One of them, near Penrioch, contains pebbles from two to four inches long. Near Penrioch also, several thin calcareous bands are intercalated in a dark-coloured schist. One of these bands, some four or five feet thick, was formerly quarried and burnt for lime. At the northern end of the island near the Cock, a fine-grained variety of schist was a good deal quarried for slates in the latter part of the last century.

In the lower part of the Pirnmill district, the schist forms a remarkable series of ridges and hollows which run along the strike or nearly so; higher up the hillsides other marked features are apparently due to joints or faults as their direction makes an angle with the strike. Near the granite the schist is much hardened, and the finer varieties assume a bluish colour. A marked set of joints seems also to have been developed in this altered rock by the action of the granite. These joints are in some places much more prominent than the foliation planes, which are nearly obliterated. (Mr. Gunn.)

The ring of altered schist around the granite is here and there several hundred yards in width. As the rock is less easily decomposed than the granite itself, it sometimes forms a ridge at a higher elevation than the granite immediately adjoining. This is well shown in Glen Catacol, and in Glen Easan Biorach where the hardened schist has been cut into narrow gorges by the streams.

CAMBRIAN.

Isle of Skye.

The chief field-work last year among rocks of Cambrian age consisted in the search for fossils in the quartzites and limestones of Skye, which have in recent years been mapped by MESSRS. CLOUGH and HARKER. Some portions of these limestones were formerly supposed to be altered Lias, but a more careful study of their geological relations, and the discovery in them of some of the characteristic fossils of the Durness Limestone proved them to be undoubtedly of older Palæozoic age.* The fossil collector, MR. A. MACCONOCHIE, was instructed to search the two districts in Skye where these rocks are displayed—the neighbourhood of Ord in Sleat, and the parish of Strath.

While mapping the Ord district, MR. CLOUGH recognised among the Cambrian rocks there developed representatives of all the zones that had been previously established in the typical ground of Sutherland and Ross-shire, from the bottom of the quartzite up to the base of the Sailmhor limestone. The limestone of Ord failed to yield any fossils even to the most diligent examination. But this want of success is not surprising when it is remembered that the corresponding lower members of the limestone series at Durness have also proved singularly barren of organic remains, only one species, *Salterella pulchella*, having been found in two thin layers near the base of the Gruidaidh group. The characteristic fossil of the Serpulite grit, *Salterella (Serpulites) Maccullochi*, appears to be of rare occurrence in that (Mr. Clough.

* See *Quart. Journ. Geol. Soc.*, vol. xliv. (1888), p. 62.

(Mr. Clough.) horizon in Skye, but MR. CLOUGH detected it at the mouth of the Ord River. MR. MACCONOCHIE proved the presence of the *Olenellus*-fauna in the "Fucoid-beds" at Tokavaig and Ord. He obtained from these strata the following fossils, which have been identified by MR. PEACH:—

Planolites, sp.	Trilobite, sp. (not *Olenellus*).
Olenellus reticulatus. Peach.	*Hyolithes*, sp.
Olenelloides armatus. Peach.	*Salterella pulchella*. Bill.

MR. PEACH has further found that the quartzites of Sleat have yielded all the various kinds of "pipes" *(Scolithus)* that characterise the zones of the "Pipe Rock" on the mainland, viz.:—

Scolithus linearis:

„ sp. No. 1 (small pipes).
„ sp. No. 2 (common pipes).
„ sp. No. 3 (trumpet pipes) = *Arenicolites* of Salter.
„ sp. No. 4 (Serpulite Grit pipes).

The first fossils found in the Cambrian rocks of Skye were obtained in 1887 by the Director-General of the Survey and MR. H. M. CADELL from the limestone slopes of the Allt a Mhullin in Strath. A few years later the Director-General and Mr. PEACH gathered some more specimens from the same locality. When the ground came to be mapped in detail, MR. CLOUGH and Mr. HARKER found fossils at many other places in the same parish. Last year, as the result of a careful search of the whole district, MR. MACCONOCHIE has greatly increased the list of species from these rocks. The united collections now amount to about 200 specimens, which have been studied by MR. PEACH, who reports regarding them as follows:—

Cambrian Fossils of Skye. (Mr. Peach.)

"I have now made a study of these fossils in order to compare them with those obtained from Durness, and to see to which of the various groups of the Durness limestone they belong. It will be remembered that in the Durness District, as shown on Sheet 114 of the 1-inch map, and in the Report of the Work of the Survey,* the limestone was subdivided into the following groups, arranged in descending order:—

Durness Limestone
- *g.* Durine.
- *f.* Croisphuil.
- *e.* Balnakiel.
- *d.* Sangomhor.
- *c.* Sailmhor.
- *b.* Eilean Dubh.
- *a.* Gruidaidh.

The following list shows the fossils obtained from the limestone of Strath, Skye, and the letters attached to the species correspond to those in the table just given, and denote the

* *Quart. Journ. Geol. Soc.*, vol. xliv. (1888), p. 403.

stratigraphical zone or zones in which the fossils occur in Durness:—

Cambrian Fossils of Skye. (Mr. Peach.

Archæocyphia minganensis, Bill. (e.)
Calathium, sp. (e.)
Sponge rods (f.)
Sponge (e. & f.)
Planolites, sp. (e. & f.)
Solenopleura, sp.
Orthisina festinata, Bill. (f.)
„ *striatula*, Emm. (e.)
Orthis, sp.
Euchasma blumenbachia, Bill. (e. & f.)
Holopea Ophelia, Bill. (e.)
Maclurea crenulata, Bill. (e. & f.)
„ „ operculum of ? (e. & f.)
„ *Emmonsi*, Bill.
„ *Oceana*, Bill. (e. & f.)
„ *Peachi*, Salt. (e. & f.)
„ „ operculum of ? (f.)
„ operculum sp. No. 2 (e. & f.)
„ „ „ „ 3 (f.)
„ „ „ „ 4 (e. & f.)
„ „ „ „ 5 (f.)
Murchisonia Adelina, Bill.
Murchisonia gracilis, Hall (e. & f.)
„ (*Eunema*) *pagoda*, Salt. (e. & f.)
Ophileta complanata, Vanux.
Oriostoma (*Pleurotomaria*) *Calphurnia*, Bill. (e. & f.)
„ sp. (e.)
„ operculum of (e.)
Pleurotomaria calcifera, Bill. (e. & f.)
„ sp. (e.)
Endoceras, sp. (f.)
„ (*Piloceras*) *invaginatum*, Salt. (e. & f.)
„ („) sp. No. 1 (e. & f.)
„ („) „ „ 2 (e.)
„ („) „ „ 3 (e.)
Orthoceras durinum, Blake (e. & f.)
„ *mendax*, Salt. (e. & f.)
„ *pertinens*, Blake (e. & f.)
„ sp. (f.)
Trocholites, sp. (f.)

"A glance at this list is sufficient to show that the limestones from which the fossils were obtained represent the Balnakiel and Croisphuil groups of Durness. Several of the species here indicated are found also in Newfoundland, where they occur in strata, all of which, according to Billings, underlie those of Cow Head, which yield *Phyllograptus typus*, four species of *Tetragraptus*, *Callograptus elegans*, and several early forms of trilobite—an assemblage that clearly points to an Arenig horizon. Accepting, as there seems good reason to do, the classification by Billings of the Newfoundland rocks, the fossils here tabulated appear to be of Middle or Upper Cambrian Age."*

Wicklow and Wexford.

In the southward progress of the revision of the Silurian districts of Ireland, the field-work has now been extended across the counties of Wicklow and Wexford by MESSRS EGAN and MCHENRY. In that region, as has long been known, certain rocks occur which have been regarded as probably older than the undoubted Silurian formations, and which have therefore been assigned to the Cambrian system. This reference, however, has been based rather on lithological than on palæontological grounds. The rocks which in the south-east of Ireland have been named Cambrian, have been compared with the typical Cambrian rocks of Wales as regards their mineral composition and aspect. But

* See *Geological Survey of Canada*, "Palæozoic Fossils" (Billings), vol. i. (1861-65), pp. 336-376.

Messrs. Egan and McHenry.) they have proved singularly barren of organic remains. Some layers of red and grey shale in Wicklow and the south of Wexford many years ago yielded certain forms which received the name of *Oldhamia*, but of which the organic nature has been disputed, and even when admitted to represent organisms, considerable difference of opinion has arisen as to their grade. These forms were at all events not found in the true Cambrian rocks of Wales, so that they could afford no assistance in determining the stratigraphical position of the rocks which contain them.

It was felt, therefore, that in the revision of the older rocks of the south-east of Ireland, an effort should be made to obtain if possible more palæontological evidence as to the stratigraphical relation of the *Oldhamia*-bearing strata, and at the same time to subject their tectonic structure to the more rigid kind of examination which the progress of research and the use of maps on a large scale have now made possible and desirable. Accordingly the Fossil Collector, MR. CLARK, was instructed to search diligently for further fossil evidence, while MESSRS. EGAN and MCHENRY, besides also examining the rocks for organic remains, made a careful study of the general structure of the ground. The result of these combined researches has been so far successful as to show that the *Oldhamia*-bearing strata probably form the oldest members of the Palæozoic series of the east of Ireland, but no palæontological evidence has been obtained to prove their Cambrian age. In the series of slates, however, which come next to and probably overlie these strata, a number of fossils have been found which appear to be undoubtedly referable to Arenig forms. If the ground were now to be mapped for the first time it is doubtful whether we should feel justified, on the ground merely of lithological characters and in the absence of reliable palæontological proof, in grouping any portion of the Palæozoic rocks of the south-east of Ireland in the Cambrian system. Probably the purple shales and quartzites which were long ago called Cambrian would be regarded as merely a subordinate part of the Lower Silurian formation into which they conformably pass, and some of the fossils of which they contain. But as these strata have for so many years been known as Cambrian, and as it cannot be definitely proved that they are not, they are retained by the Geological Survey in the position which they have held for so long a time. As they are so closely linked with the Lower Silurian rocks of the district in which they occur, the account of recent investigation regarding them is given in the next section of this *Summary*.

SILURIAN.

Wicklow and Wexford.

Messrs. Egan, McHenry, and Clark.) In beginning their field work last season MESSRS. EGAN and MCHENRY instituted an exhaustive search within the Cambrian

and Silurian areas of the County Wicklow and the northern parts of Wexford. They succeeded in finding fossils in many new places, and have thus provided a broader and more reliable basis for working out the structure and stratigraphy of this complicated region. The oldest strata, to which we propose to continue to apply the term Cambrian, consist of massive quartzites and red and purple shales. It is these shales that have long been known to yield *Oldhamia*. The more recent researches of the Geological Survey have brought to light numerous branching rod-like stems both in the quartzite series and in the ribband slates that come next to it. These were abundant in the rocks which have long been distinguished as "Cambrian" at Sugar Loaf Mountain, south of Bray, in Bray Head railway-cutting, and near Newcastle. Of the specimens from Bray Head (Oldhamia-beds), PROFESSOR LAPWORTH remarked that they are "undoubtedly of organic origin." MR. NEWTON found among the specimens from Bray Point railway-cutting, markings that may have been made by annelides; in those from Little Sugar Loaf Mountain, slender rods (*Nematolites?*) and other markings, resembling graptolites, but possibly not organic; in those from Greystones, other small rods, markings like burrows, and some which might possibly be graptolites. (Messrs. Egan, McHenry, and Clark.)

It thus appears that in the quartzite series, though it has been assigned to the Cambrian system, not a single distinctively Cambrian fossil has yet been detected, even after a prolonged and careful scrutiny.

The next stratigraphical group affords much more satisfactory palæontological evidence as to its age, which is now definitely ascertained to be that of the Arenig division of the Lower Silurian formations. It consists of an important and persistent set of slates or shales which has been named the "Ribband Series." It is on the whole sharply marked off from the quartzite series. Sometimes the two are separated by a line of fault; in other places they have been much crushed together, so that it becomes difficult to draw a definite line between them. There is no evidence that they are separated from each other by any stratigraphical break. The Ribband Series received its name from the earlier observers, on account of the regularly striped alternations of darker and paler layers in the more argillaceous portions. Its prevailing colour is grey, but buff, red, and purple tints sometimes predominate. It has been traced by MESSRS. EGAN and MCHENRY over wide tracts of Wicklow and Wexford, being clearly distinguishable by its lithological character from the quartzite series on the one hand, and from the Llandeilo and Bala rocks on the other. Though on the whole barren of organic remains, it has furnished recognisable Arenig fossils at Rock Little, south of Arklow; at Breanoge Head, south of Courtown, and at Kiltrea, four miles west of Enniscorthy.

Messrs. Egan, McHenry, and Clark.)

The following fossils from the Ribband Series have been determined by MR. NEWTON and MR. PEACH :—

Oldhamia radiata (?) (2 miles N.E. of Arklow).
Bryograptus Kjerulfi or *Callavei*.
Dicellograptus.
Dichograptus (?).
Didymograptus patulus or *latus*.
Phyllograptus (?).
Tetragraptus (?).
Caryocaris Wrighti.
Acrothele (?).
Obolus.
Burrows, tracks, slender rods, &c.

The older rocks of the south-east of Ireland have undergone the same kind of crushing and deformation which has been traced through the similar districts further north. Besides abundant plication and crumpling, the Ribband Series often presents its grit bands in a curiously broken-up condition, portions of grit having been pushed into the argillaceous strata, so as to produce a brecciated appearance, deceptively like that of conglomerate; indeed some of these crush-breccias have actually been described as conglomerates.

Next to the Ribband Series there are occasionally found certain black slates, which have yielded graptolites of undoubtedly Llandeilo age. These slates, however, only make their appearance here and there, and do not seem to cover any large space of surface. They may be seen on the shore to the north of Courtown, where they come up again and again together with the Bala limestone. From these black shales, as exposed in the shore north of Courtown, MR. CLARK has collected *Cœnograptus gracilis*, *C. pertenuis*, *Leptograptus flaccidus*, *Diplograptus mucronatus*, *Dicellograptus*, *Dicranograptus Nicholsoni*, *D. ramosus*, *D. zic-zac*, and *Climacograptus perexcavatus*—an assemblage of organisms characteristic of the Glenkiln (Upper Llandeilo) sub-division of the Moffat shales in the Lower Silurian series of the South of Scotland. He has also obtained a number of graptolites from the railway-cutting near Rathdrum, where the black shales are to be seen.

Limestones belonging to the Bala subdivision of the Silurian system have long been known to occur in Wicklow and Wexford, and are shown upon the published maps. They have yielded an abundant and characteristic Bala fauna. No evidence of Upper Silurian strata has been met with in Wicklow or Wexford.

In the course of the revision of the sedimentary rocks attention has been paid to the igneous rocks which form so conspicuous a feature in the geology of the south-east of Ireland. According to the published maps two bands of these rocks traverse the region. One band begins a little south of Wicklow and stretches south-westward beyond Croghan Kinshela; the other and more important belt, starting from Arklow Head, runs for nearly 80 miles across Wexford and Waterford to the southern coast near Dungarvan. These long interrupted strips of igneous material have been represented on the published maps of the

Geological Survey as consisting partly of intrusive sheets of both acid and basic material, and partly of intercalated sheets of acid lavas and of tuffs ("felspathic ash" and "greenstone ash"). As these maps were published from 40 to 50 years ago, and as petrography has made great progress in this long interval, it was only to be looked for that some changes would be required both in the nomenclature and in the mapping of the igneous rocks. Some progress has been made in this revision, though not enough to warrant any full statement of the alterations which are now seen to be required. Enough of ground, however, has been re-examined to confirm the suspicion aroused some years ago when the DIRECTOR GENERAL and DR. HATCH studied the sections laid bare in the Aughrim Valley above Wooden Bridge that much of the so-called "greenstone ash" was not really of fragmentary or pyroclastic origin, but consisted of dykes and sills of acid, intermediate, or basic material which had acquired a laminar structure as the result of severe compression and deformation. As far as the revision has advanced none of the "ashes" have proved to be tuffs at all. Every example met with throughout County Wicklow has been found to be only a crushed variety of some felsite or other eruptive rock, or occasionally felspathic grits. Some of these "greenstone ashes" are bands of hornblende-schist representing what was once basic intrusive material. (Messrs. Egan, McHenry, and Clark).

The sheets of rock delineated on the map as long bands of interbedded lava, so far as they have yet been studied, have furnished no evidence of contemporaneous outflow. But on the contrary numerous proofs have been met with of actual intrusion. It is too soon to decide that no true lavas occur in the more northerly of the two bands of igneous material, but no satisfactory proofs of their presence have yet been encountered. It would certainly seem that a very large proportion of the "felstones," "quartziferous porphyries," and "greenstones" are really intrusive bosses and sills.

That true volcanic rocks occur in the southern band, however, is beyond doubt, though there may be some difficulty in fixing the stratigraphical limits of the volcanic activity. Some of the best sections of these rocks have been laid bare by the sea on the coast north of Courtown in County Wexford. There some fine cliffs of coarse agglomerate and fine bedded tuffs form part of a long succession of sea-precipices in which the extraordinary complication of the geological structure of this part of Ireland is well displayed. The relations of the volcanic rocks to the ordinary sedimentary strata are often much obscured by crushing and faulting. That the tuffs are later than the Llandeilo series is shown by the occurrence of pieces of the characteristic black shales in them. That they are also later than some part of the Bala group is indicated by their including pieces of the fossiliferous Bala limestone. A little north of Duffcarrick Rocks a bed of conglomerate dips away from the Bala limestone, of which it contains abundant fragments. The conglomerate passes upwards into fine tuffs, followed again by the Bala limestone and shales

sers. n, Ienry, Clark.)

and by more tuffs. This complicated section has not yet been thoroughly unravelled, but it seems to indicate that volcanic discharges took place during a part of the Bala period, accompanied perhaps by local disturbance and consequent unconformability.

The igneous rocks are now being studied petrographically by MR. H. J. SEYMOUR, and his determinations will greatly aid the colouring of the revised edition of the maps. An account of his researches among these rocks will be given in a subsequent *Summary of Progress.*

Central and Southern Ireland.

The revision of the Silurian rocks of Ireland was last year carried by Mr. KILROE through the counties of Tipperary, Limerick, Cork, Kilkenny, and Waterford. In portions of the ground he was preceded by MR. CLARK, who searched the rocks for palæontological material to aid in determining their stratigraphical position. MR. KILROE, throughout the area examined, has found the strata to consist for the most part of dark grey and blue mudstones, with intercalated bands of dark grey, blue, and greenish grits. They usually dip at a high angle, and frequently show contortion and folding; so that beds and groups of beds are probably repeated. Cleavage is more or less perceptible throughout the several inliers, and is very fully developed in the rocks of the more southerly areas. The cleavage faces in certain places show a sericitic glaze.

per Hill rict. . Kilroe.)

The rocks of the Keeper Hill district, which are the continuation southward of those which form the Devil's Bit Hills, are chiefly of Llandovery age, though some representing a higher horizon also occur, as is the case further north. A wide zone stretching south-westward from Upper Church by Holyford has yielded an abundance of fossils at various places. The specimens named by MR. NEWTON include *Monograptus priodon* var. *Flemingii*, *M. colonus*, *M. intermedius* (?), *M. spiralis* (?), *Cyrtograptus hamatus*, *C. Carruthersi*, *Athyris or Glassia*, Crinoids.

As *Monograptus colonus* and *M. intermedius* are characteristic of Wenlock and Ludlow rocks, *Cyrtograptus* of Wenlock, and *Monograptus priodon* of Wenlock and Tarannon, it would seem that rocks as young as Wenlock exist in this zone. The graptolites almost universally occur in thin flaggy seams, and layers of fissile grit, which weather brown and display flattened carbonaceous markings on their bedding-planes. These peculiar seams seldom make their appearance in the grits and mudstones outside the fossiliferous zone above referred to, and those bearing fossils are of still rarer occurrence. Accordingly fossil localities are sparingly distributed over the large area extending westward from the edge of Sheet 144 to the Old Red Sandstone boundary. At the northern margin of the same Sheet, due south of Keeper Hill, fossil-bearing strata were met with, similar to those near

Holyford (Sheet 145); an arrangement which may possibly indicate that a synclinal trough of Wenlock rocks exists there. Keeper Hil District. (Mr. Kilro

An outcrop of limestone, the only one met with in the entire Devil's Bit and Keeper Hill region, was observed in the Clare River bed, near the Old Red Sandstone boundary, south of Castle Waller (Sheet 144). The outcrop, which probably coincides with the summit of a sharp anticline, may be one of Bala rocks, though unfortunately no fossils were found to establish the horizon of the strata.

The rocks in the southern part of the Galtymore area are so highly cleaved that if fossils originally existed in them they must now with difficulty be obtainable. Some, however, have been found by MR. CLARK in the disused slate quarry near Darragh Bridge (Sheet 165). In the northern portion of the district numerous specimens of graptolites were found in the townland of Ballynamuddagh, on the north flank of Temple Hill (Sheet 165); and in Lyre (Sheet 154) along the stream which forms the county boundary, north of Slievecushnabinnia. All the specimens collected have been assigned by MR. NEWTON to *Monograptus riccartonensis*, and may indicate rocks of Llandovery (Gala) age.* Galtymore District. (Mr. Kilro

An interesting circumstance which tends to establish the correlation of these rocks with the Upper Silurian series of southern Scotland, is the occurrence in them of a fossil which bears a close resemblance to, if not identity with, *Protovirgularia* (M'COY). Several specimens of the fossil were found at a point about 300 yards south by west of Knockaucbraek Bridge, three miles east of Galbally (Sheet 154).

It is believed that all the older Palæozoic rocks under notice, in this tract and in the narrow strips on the north flank of Slievenamuck, are of Upper Silurian age, no evidence, lithological or otherwise, having been noticed for the existence of Lower Silurian rocks in either area.

The area of Slievenaman, which lies to the north of Carrick-on-Suir, contains a preponderance of slates, which, with the grits that accompany them, are identical in character with those of the Mitchelstown tract; where, on the other hand, grits predominate. Several slate quarries have been worked in the region due north of Carrick (Sheet 167) and south of Windgap (Sheet 156); and slates are still obtained and manufactured at the Victoria and Ormonde Quarries in that region. From the prevalence and perfection of the cleavage, which most usually crosses the bedding, it might appear unlikely that fossils should be found in the tract; nevertheless some organic forms have been discovered, both at the disused quarries north and east of Carrigadoon Hill, and at the Victoria Quarries beside the Lingaun River, due north of Tinnakilly. The specimens that lie upon the cleavage faces consist of various branching fucoids. Slievenam District. (Mr. Kilro

* It should be noted, however, that in the South of Scotland *Monograptus riccartonensis* occurs both in the Gala group (Tarannon) and in the Wenlock rocks of Riccarton, from which it takes its specific name, and that it is most common in the latter strata.

Slievenaman District. (Mr. Kilroe.)

Occasionally they lie across lines which mark the original bedding of the mudstone. Graptolite-like impressions were also found which show a serrated edge on one side, the other side being plain like the stem of a single graptolite. The impressions are all much flattened, broadened, and lengthened, sometimes waved and distorted. Mr. Newton says of them: "The specimens are interesting, as showing what cleavage may do, but they are a puzzle. The most perfect of them look like graptolites, and may possibly be the much altered remains of such organisms; but other examples suggest that they are altogether due to cleavage and are not organic." These specimens were also seen by Prof. Lapworth, who formed a similar opinion in regard to them. It is difficult to conceive how such striking impressions could result, with more or less uniformity of shape and outline, from the mere mechanical rearrangement of particles in a homogeneous rock. They are sufficiently rare to accord with the supposition that they represent linear fossils caught perhaps along the junctions of cleavage- and bedding-planes. They are numerous enough, however, to have attracted the attention of Mr. Hughes, the well-informed manager of the Victoria Quarries, who has made a considerable collection of them. Specimens were presented to the Survey many years ago by Mr. Budd, of Waterford, and were placed in the Museum as *Graptolithus Hisingeri* by the late W. H. Baily.

Glenpatrick and Portlaw District. (Mr. Kilroe.)

Immediately south of Carrick-on-Suir, the district of Glenpatrick and Portlaw displays dark grey slate alternating with important bands of grit. The latter are usually ferruginous, weather brown, and are barren of organic remains. The slate, which is well exposed in Glenpatrick, was formerly extensively quarried there, at a point seven miles west by south of Carrick-on-Suir. It was found by the Survey Collector, Mr. Clark, to contain impressions similar to those found in the slate north of Carrick. Indistinct organic forms were also found in the slate at Clonea and near Rathgormuck.

The fucoid remains and graptolite-like impressions here referred to constitute the only fossil evidence yet obtained upon which a conclusion as to the age of the Silurian rocks north and south of Carrick can be based. If the impressions were really those of single graptolites they would support the belief entertained on lithological grounds that the rocks as far south as Croughaun Hill—the southern limit of the area MR. KILROE has examined—are of Upper Silurian age. The rocks are identical in general character with those of the Mitchelstown and Keeper Hill tracts, where Upper Silurian fossils abundantly occur. No fossil evidence has been found for the introduction of any Lower Silurian colour on the maps of these tracts. Finally, the strata decidedly differ in lithological character from those containing Lower Silurian fossils at Tramore.

It may be added that the slate in all the regions now reviewed is identical in character with that of the Slieve Bernagh tract, and of Slieve Arra on the opposite side of Lough

Derg. This similarity has been pointed out by MR. KINAHAN, (*Geology of Ireland*, pp. 28 to 33). Glenpatrick and Portlaw District. (Mr. Kilroe.

The coarse grit and fine conglomerate bands of the Slieve Bernagh and Arra tracts have their counterparts in beds which have been represented as "ash," north of Carrick-on-Suir. The material these beds consist of is a mixture of large and small grains of quartz, with some of felsite, chert (?), and fragments of black, grey, and greenish slate, similar to specimens that have been obtained from the Silurian area of West Wicklow and East Kildare, to which reference will be made a little further on.

Since his appointment in April last, MR. HENRY J. SEYMOUR has been engaged in arranging, registering, and cataloguing the collection of microscopic slides of Irish rocks in the Office of the Survey in Dublin, which now number 2,181. He has had 162 new slides prepared, chiefly of Silurian igneous rocks, and has supplied the field-surveyors with determinations of the rocks for the guidance of the mapping. The specimens which he has studied and reported on were collected mainly from three districts—near Slane in Co. Meath, in Co. Cavan, and in the counties of Wicklow and Wexford. Petrography of Irish Silurian rocks. (Mr Seymour.)

Petrographically, the specimens examined from the Slane area are divisible into volcanic tuffs or breccias and intrusive igneous rocks. The first are of medium coarseness, and the rock-fragments composing them are mainly andesites. This material is usually finely crystalline in texture, and is frequently associated with lapilli of a scoriaceous glass, no doubt of similar chemical composition. When, as is frequently the case, fragments of both these varieties occur in the same rock-specimen, it appears in section remarkably similar to the volcanic tuff of Hyssington, Shropshire. Felsitic inclusions are not uncommon, and these often exhibit perlitic structure (I. 1,624). The ejected plagioclases are mostly andesine. The occurrence of rolled fragments, and, in one case, of fossils, points to the deposition of these clastic materials in water, together with the ordinary fragmental rocks of this area. One of the specimens examined contains anatase. The rock in which this mineral occurs is much decomposed, and is made up of clear quartz grains, and a greenish material which appears to represent altered andesite. The anatase crystals, which are very numerous, occur in the quartz; they are about 0·03 mm. in size, show the characteristic crystalline forms, and are pale brownish yellow in colour.

All the tuffs have suffered from weathering, and secondary calcite and chlorite are more or less extensively developed in them. The presence of vesicular fragments affords evidence that some of the rocks have not undergone extreme compression. Certain specimens from the district, however, have been foliated by pressure. A peculiar type of silicified limestone (1,625 and 1,627) occurs near Slane, in which the silica is present in perfectly developed acicular quartz crystals.

The eruptive rocks examined are mainly altered basic varieties. They include examples of andesites, sometimes porphyritic, dolerites, and basalts with olivine; this mineral, however, being

trography Irish urian ks. (Mr. ymour.)

entirely represented by pseudomorphs. Augite is the chief ferromagnesian constituent, but hornblende and biotite also occur; the plagioclase varies from andesine to labradorite. A kersantite occurs near Craig Baron Hill, and an augite-syenite at Dunmore.

The rocks collected from Cavan (Sheet 69) have been mapped and described as felspathic ashes and tough flaky breccias. Microscopical examination shows that this determination is correct. They are mainly schistose fragmental rocks of basic composition, and usually much altered. Lumps of andesite (diabase) and basalt, sometimes of considerable size, occur in a base of finer material, now composed of chlorite, calcite, and iron ores. Sometimes the larger inclusions show evidence of crushing, but in other cases are apparently unaffected, Scattered augites and plagioclases are generally present in the ground-mass.

In the Silurian area which lies to the west of the great ridge of the Leinster granite, and is comprised in the one-inch Sheets 120 and 129, a number of outcrops of "Greenstone ash" are noted on the published maps. As in the Wicklow region already referred to, none of these "ashes" have on recent examination been found to be tuffs. Specimens representative of a limited number of them were sliced and examined, and proved to be of two types, *foliated grits* and *hornblende schists*. So far as an opinion may be formed from the topographical position on the map, of the specimens collected, each type seems to occupy a distinct area, the hornblende-schist occurring only within a zone about a mile in width next the granite, while the grits appear exclusively outside that zone.

The foliated igneous rocks are of the usual type of hornblende-schists; they often contain biotite, which in some cases at least, is a product of the alteration of the hornblende. The latter has also been altered into epidote, indeed almost every slice examined contained this mineral to a greater or less extent. Sphene is often present in well developed crystals. These rocks were possibly pyroxenic varieties in their original condition. The foliated grits vary considerably in texture, and appear to mark coarser layers in the Silurian sediments. They have shared in the general crumpling which the rocks of the district have undergone, and have thus acquired a schistose structure. Under the microscope, they are seen to be mainly composed of quartz and shaly particles. Occasionally small pieces of andesitic lavas and plagioclase crystals are present in them.

Upper Silurian rocks of Central Scotland.

narkshire d Ayrshire. Ir. B. N. each.)

Further research has been carried on among the Upper Silurian rocks of Scotland, from which so remarkable a series of organic remains was announced in the *Summary of Progress* for 1897. When making a preliminary examination of the fossils gathered during last year from the Ludlow and Downtonian rocks of Lanarkshire and Ayrshire, preparatory to distributing them among specialists for examination and description, MR. PEACH

observed two more specimens of the remains of myriapods allied to *Kampecaris* and *Archidesmus*. The form referred to in last *Summary of Progress* as being the first recorded instance of a Silurian air-breather of this class is therefore no longer unique. It has been studied by MR. PEACH during the past year, and described to the Royal Physical Society of Edinburgh under the name of *Archidesmus loganensis*. The genera *Kampecaris* (Page) and *Archidesmus* (Peach) were made to admit two species of simply constructed millipedes from the Lower Old Red Sandstone of Forfarshire, in which the body segments were all single. In virtue of this peculiarity they have been elevated by DR. SAMUEL SCUDDER into family rank under the name of the Archidesmidæ. All the new forms appear to belong to this family, and though *A. loganensis* seems to differ widely from *A. MacNicoli*—the Lower Old Red Sandstone form—it has been provisionally placed in the same genus with it.

Lanarkshire and Ayrshire (Mr. B. N Peach.)

As was announced in the last *Summary of Progress*, the fishes found in the Upper Silurian formations have been handed over to DR. TRAQUAIR, who supplies the following note on the new forms discovered during the past year :—

Silurian fossil Fishes. (Dr. Traquair

"Among the additional specimens of Silurian (Downtonian) Fishes collected by MR. TAIT in the Lesmahagow district, I have found a specimen from Seggieholm which throws light on some undeterminable fragments alluded to in my notes of 1897. It is the type of a new genus and species to which I have given the name *Ateleaspis tessellata*, and although in its form it displays an affinity with the Cœlolepidæ, a new family Ateleaspidæ must be erected for its reception.

"Among the detached and isolated fish-scales and plates collected by MR. TAIT from the Downtonian rocks of the Pentland Hills, remains of *Ateleaspis tessellata*, Traq., *Birkenia elegans*, Traq., and *Lasanius problematicus*, Traq., may be recognised, but in no case has anything like an entire fish, or portion of a fish, occurred in that locality."

Several good specimens of a new species of *Eurypterus* of the type of *E. scorpioides*, Woodw., were collected last year from the Downtonian rocks of Ayrshire and Lanarkshire. This species was doubtfully referred to MR. LAURIE'S genus *Drepanopterus* in the *Summary of Progress* for 1897 (p. 85) as it is ornamented with a sculpture similar to that seen in this genus; but the more complete specimens since obtained clear up this point. The specimens have been handed to MR. LAURIE for description, together with some other new forms in the Survey Collection, found in the Upper Silurian and Lower Old Red Sandstone strata. The Downtonian rocks have also yielded several specimens of a curious chain of disc-like bodies, connected in some instances by a slender thread of the same substance as the discs, much like a string of flattened beads. As a rule these discs are represented by a rusty ochreous decomposed material, but one or two specimens show a structure suggestive of a sponge. Accordingly a collection of about 40 specimens was forwarded to DR. G. J. HINDE, who observes regarding them :—"The markings on some resemble very closely sponge spicules, and in a general way one would have little doubt in regarding them as sponges." . . . . "But while these spicular markings may be accepted

Silurian Eurypterids (Mr. Peach.

Silurian Eurypterids. (Mr. Peach.)

as indicating the sponge character of these bodies there are no definite spicular forms shown to give a clue to their relationships." . . . . . "Only on the forms quoted above are spicular impressions preserved. In regard to the other specimens forming the large majority of those sent, only the outlines in formless rusty material are shown, and whilst these are very distinct, there are no traces of spicules to be found, and thus it is a difficult thing to determine whether they are related to the few forms with the spicular markings which might be provisionally placed with the sponges. I do not think there is anything very improbable about these connected lobes being sponges; the form is unusual, but there are instances where single rounded forms occur as fossil (e.g. *Phormosella ovata*, Brit. Foss. Sponges, Pal. Soc., 1887, Pl. III., Fig. 2) in much the same condition of preservation, only showing the spicules. But until one could obtain further evidence I should hesitate to describe them positively as sponges." Until the nature of these bodies has been more definitely ascertained they may be provisionally placed among the sponges, to which at present they appear to show most affinity.

Old Red Sandstone.

Caithness.

The field-work of the Survey has been carried on during the last season in three of the great basins, in which the older portion of the Old Red Sandstone of Scotland was deposited. In the most northerly of these, that which embraces the county of Caithness, Mr. Pocock continued the mapping to which reference was made in the *Summary of Progress* for 1897. He traced the Old Red Sandstone of the conspicuous group of the Morven Hills and found it to cover the whole area between the quartzite of the Scarabin range and the detached quartzite mass of Con na Craigie, not as an outlier, which it has been supposed to be, but as a continuation of the main mass of the formation lying to the east. It lies, as is well-known, with a complete unconformability on the crystalline schists and granites of the region. Its limits, which were traced last year in the neighbourhood of Glut Lodge, have been followed eastwards for a distance of over four miles along the north side of the Dunbeath Water, after which the boundary-line swings back to the west, crosses the watershed into the Berriedale valley and runs as far as the foot of the Small Mount west of Morven. The general features of the basement-beds described in the Director-General's Memoir, (*Trans. Roy. Soc. Edin.*, vol. xxviii, 1878, p. 375, *et seq.*) have been verified in the Braemore area. The following sub-divisions in descending order have been mapped:—

Mr. Pocock.)

2. Morven conglomerate, consisting of unstratified conglomerate or breccia passing up into stratified pebble-beds; 450 feet to the top of Morven.

1. Braemore group, consisting of red and grey flagstones, red sandstones and shales passing up into arkoses and pebbly grits with coarse breccias; locally 900 feet.

The lowest beds of the series are well exposed in the river section near Braemore Lodge. No basal breccia is seen at this point, the lowest beds visible being red flaggy sandstones with intercalated arkoses mainly composed of pink orthoclase derived from the orthoclase-gneiss which has been described in the account of the crystalline schists of this area. Not far from the base, beds of dark grey calcareous flagstone, similar to the flagstones of Eastern Caithness, have yielded fossils regarded by MR. PEACH as plant-remains. These beds are only traceable for a short distance, and rapidly give way to a local quartzite-breccia formed round the quartzite mass of Con na Craigie. But grey shaly flagstones of similar type and probably on the same horizon are found under the arkoses and conglomerates of Ben Bhreac on the north side of the Dunbeath Water. The occurrence of local breccias is an interesting feature in the Braemore group. They are composed almost exclusively of angular fragments of the rocks immediately underlying them, contain little or no matrix, and occur wherever a hummock of the older rocks stands up through the basal sandstones of the group. They are themselves covered by higher beds of red sandstone and shale. They point to a time when the waters of the northern basin of Old Red Sandstone, to which the name of "Lake Orcadie" has been given, extended in a long bay full of rocky islets from the region of Dunbeath to where the Morven Hills now stand, while the low watershed on the north stretched eastwards as a tongue of land separating the Morven bay from another inlet in the Dunbeath valley. The disintegration of the rocks under atmospheric agencies gave rise to coarse screes, which were buried *in situ* as the waters of the lake rose above them. Subsequently, during the deposition of the higher parts of the Braemore group, the land must have sunk so as to submerge the watershed on the north side of the Berriedale valley to a depth of many hundred feet. The breccias occur at several different horizons, and as noticed in the Director-General's Memoir, change rapidly according to the nature of the underlying rock. The quartzite breccia on the col between Morven and the Small Mount proves to be a local base about 500 feet above the bottom beds of the Braemore group. The upper parts of this group form the lower slopes of the Morven range. They consist of strata coarser in grain and more pebbly than the lower parts, whilst intercalations of dark coloured grits and arkoses with pebbles of granite, gneiss, and quartz, frequently occur in them. These pebbly beds are more conspicuous on Morven than on Smean and Maiden Pap, indicating that the shore-line probably lay to the west. The Morven conglomerate forms three outliers rising into prominent crags on Morven, Smean, and Maiden Pap. It is also seen on the north side of the Berriedale water and again on the top of the hills to the east of Glut Lodge. It is made up of boulders, rounded and subangular, lying at different angles, crowded together in a sandy matrix, which here and there contains a good deal of pink orthoclase. The boulders are derived from the granites and crystalline schists of the district,

(Mr. Pocock.

Mr. Pocock.) and in addition a few red sandstone blocks occur. At the top of Morven and Smean the conglomerate passes up into well stratified pebble-beds, the pebbles being only one or two inches in diameter and well rounded. They consist of the same materials as those in the boulder-bed below.

The Old Red Sandstone of this district is far more disturbed than that of eastern Caithness. Inclinations as great as 50° are common among the sandstones of the Braemore group. But though the higher beds are less disturbed than the lower, no break in the succession of strata has been detected.

Ross-shire.

Mr. Peach.) Further south, in the county of Ross, additional tracts of the same northern basin of Old Red Sandstone were mapped by MESSRS. PEACH, HORNE, and HINXMAN. MR. PEACH'S area was a comparatively small one in the district of the Black Isle, where he traced the red and yellow false-bedded sandstones which there form the uppermost member of the system. He found among their occasional bands of conglomerate and nests of pebbles, abundant detritus of the schists of the region, and also some pieces of a decomposing dark purple andesite, which may possibly indicate contemporaneous volcanic activity somewhere in this part of "Lake Orcadie."

Mr. Horne.) The area of Old Red Sandstone in that portion of the Black Isle mapped by MR. HORNE last year forms a strip about three miles broad, extending from Fortrose on the Moray Firth westwards to the Cromarty Firth. The strata there exposed may be grouped in the following descending order:—

6. Red and yellow sandstones, false-bedded, sometimes calcareous, with occasional scattered pebbles merging into conglomeratic sandstones.
5. Conglomerate with rounded and subangular pebbles (Ordhill and Rosehaugh).
4. Red sandstones, flagstones, and shales, with a band of shales containing limestone nodules, underlain by a thick group of felspathic sandstones (arkose), red flagstones and shales.
3. Conglomerate (with subangular pebbles of crystalline schists and granite), seen at waterfall, Rosemarkie Glen.
2. Hard grey calcareous flags and shales, with thin ribs of impure limestone. Rosemarkie Glen.
1. Basal breccia. (Whinhill, north side of Rosemarkie Glen.)

In the course of his detailed work, MR. HORNE obtained evidence confirming the views held by previous observers regarding the synclinal arrangement of the Old Red Sandstone in the region of the Black Isle. This structure was long ago recognised and described by HUGH MILLER, and subsequently by the present Director General of the Survey, while the northern portion of the district was mapped by the late MR. HUGH MILLER of the Geological Survey. (Sheet 94 of the Map).

The lowest rocks are exposed in the picturesque ravine west of Rosemarkie, and on the adjacent hill-slopes. The basal breccia (No. 1) is not visible in this gorge, being thrown out by

a fault, but it occurs on the declivity to the north, between (Mr. Horne
Whinhill and Woodside. It contains sub-angular fragments of granulitic quartz-schist, biotite-gneiss, and pieces of the adjacent pink granite. The shales and flags of No. 2 are exposed on both sides of the gorge of the Rosemarkie Burn, where they are faulted against the pink granite and are themselves traversed by small faults. They dip at high angles, and have been subjected to sharp folding. The coarse conglomerate (No. 3) forms a waterfall at the head of the glen, where it is seen to overlie the grey calcareous flagstones and shales (No. 2), both being traversed by small faults. The lower portion of group No. 4, consists of a thick succession of coarse felspathic sandstones which have evidently been largely derived from the disintegration of granitic rocks. Large fragments of felspar, not much assorted by water, form the main constituent, so much so that the rock resembles in places a granitic breccia. But the derivative character of the material is made further apparent by small scattered pebbles of granite, pegmatite, and grey quartz-granulite. The strata are visible on the beach at low tide, between Fortrose and Avoch, in the crags that form the ancient shore-cliff of the same piece of coast, and in the railway-cutting east of Avoch Station. They are, however, much brecciated,—a result doubtless of the powerful fault that skirts the base of the eastern cliff of the Black Isle. These felspathic sandstones are likewise visible on the hill-slope to the east of Fortrose. In the Shaltie Burn, near Mains of Avoch, a thin band of red shales with limestone nodules, about two feet thick, is interleaved in red flags and sandstone. Near the top of this group lies the red sandstone of Arkendeith, one of the valuable building stones of the district.

Next in order comes a band of conglomerate (No. 5), which is traceable from the Ordhill south-westwards by Rosehaugh in the direction of Munlochy. Towards the north-east it seems to merge into conglomeratic sandstone; at least, it is not traceable as a separate zone north of Ordhill.

The strata that form these five sub-divisions, have a general inclination to the W.N.W. or N.W., that is away from the axis of crystalline schists which runs from Rosemarkie north-eastwards in the direction of Cromarty. Close to that axis the angle of dip is high, varying from 50° to 70°, but it decreases westwards to 40° and 25°.

These groups are surmounted by red and yellow sandstones (No. 6), occupying the centre of the syncline of Easter Ross and covering a large area in the southern portion of the Black Isle. Excellent building stone is obtained from this group, several quarries being now in active operation (Millbuie, Suddie, Tarradale). Recently a quarry was opened on the Rosehaugh estate which has yielded a beautiful yellow sandstone, from which the new mansion house of Rosehaugh has been built. The synclinal structure is amply proved by the evidence obtained along the southern slopes of the Millbuie Moor in the direction of the Cromarty Firth. North of Rosehaugh, these sandstones dip to

(Mr. Horne.) the N.N.W. and N.W. at angles from 10° to 12°. Westwards by Belmaduthy they dip N. and N.N.E., while about a mile to the north of Belmaduthy they dip to the N.E. at gentle angles. Again, on the western slopes of the Black Isle, near Ferintosh, these yellow sandstones have an easterly dip from 5° to 10°.

Along the south-east side of the Black Isle, several strong springs issue from these sandstones which have proved valuable sources of water-supply for Rosemarkie, Avoch, and Rosehaugh.

An interesting feature of these uppermost sandstones is the occurrence, already referred to, of pebbles of andesite or diabase-porphyrite in them. The specimens observed by MR. HORNE were from one to three inches across, and resembled the andesite-lavas associated with the Old Red Sandstone on the south side of the Moray Firth (Gollachie Mill, Gartly, Rhynie). These pebbles have not as yet been detected on lower horizons in this district.

Beauly District. (Mr. Horne and Mr. Hinxman.) Besides the ground surveyed by him in Easter Ross, MR. HORNE also mapped a small tract of Old Red Sandstone in the district of Kiltarlity, south of the town of Beauly. In that part of the basin of Lake Orcadie, the lowest coarse tumultuous conglomerate attains a great development, as recorded by MR. WALLACE, of Inverness. Its unconformable junction with the crystalline schists is well seen in the Breakachy Burn, a tributary of the Beauly west of Beaufort Castle. The crystalline schists likewise appear, surrounded by conglomerate, in the picturesque gorge of that river south of Teanassie. Again, along the southern margin of the Old Red Sandstone, the basal conglomerate caps Meall Mor, north of Loch a Bhruthaich. Generally, it shows little or no trace of stratification, and many of the blocks are subangular. The smaller pebbles have been locally derived, being composed of grey quartzose granulites, mica-schists, and biotite-gneiss. The larger and more highly-rounded blocks, which must have been carried from a distance, consist of granite and pegmatite. In places, this conglomerate has intercalations of sandstones and flags, as in the streams in Boblanie Wood, and in Glen Convinth.

(Mr. Hinxman.) In an adjoining part of the same district some additional area of the Old Red Sandstone was mapped by MR. HINXMAN, who reports the same general results as those obtained by MR. HORNE. He traced the coarse conglomerate-breccia at the base of the series in the valleys of the river Orrin and other streams flowing from the west. It is there well displayed, and presents the appearance of a coarse tumultuous aggregate of large angular, subangular, and rounded blocks, set in a hard sandy matrix with small rounded pebbles. This matrix is, however, sometimes completely absent. The great majority of the included blocks are derived from the underlying schists, those of quartz-schist predominating. There are also boulders of red granite, generally more or less foliated, pegmatite, coarse granitoid gneiss, hornblende-schist, and hornblende-rock. It is noticeable here, as at Kiltarlity, that these boulders are usually much larger and more rounded than the fragments derived from the local schistose rocks, though in the Allt Goibhre, near the unconformable

junction, the breccia contains angular masses of mica-schist six and eight feet in length. (Mr. Hinxman.)

The upper part of the conglomerate is intercalated with shaly bands, which pass upwards into a series of grey micaceous flags and shales. These are well seen at the Bridge of Orrin, where they dip S.S.W. at 15°–25°, but rest at lower angles of 5°–10° in the Allt Goibhre. The flaggy series is succeeded by thick-bedded red and greenish-grey micaceous sandstones, with a few pebbly bands, and seams of green and purple micaceous shale. The sandstones are often false-bedded, while the true bedding is indicated by partings and galls of red clay. Near Redcastle the beds dip N.N.E. at low angles, and further to the west seem to be almost flat. This series affords an excellent freestone, which is largely quarried in the district. The quarries at Redburn, near Beauly, have supplied building material for the Priory at Beauly and for Beaufort Castle.

Loch Garve. (Mr. Peach.)

An interesting feature in the mapping of the Geological Survey in the north of Scotland has been the discovery from time to time of outliers of Old Red Sandstone, sometimes a number of miles distant from the main body of the formation. The latest outlier of this kind was found last year by MR. PEACH while engaged in surveying the crystalline schists of Ross-shire, in the district of Lochs Luichart and Garve, which have already been referred to. It stands on the hill called Craig a Chaorinn, which overlooks the south-western angle of Loch Garve. It consists of a coarse conglomerate made up of rounded and more or less angular fragments of Moine-schist, muscovite-biotite-gneiss, with a few fragments of hornblende-schist and augen-gneiss. The blocks are huddled together with little or no finer matrix. The preservation of this outlier is evidently due to a mica-trap which ascending from a dyke or sill that traverses the underlying schists, has forced its way between the pebbles and cemented them together. The conglomerate has evidently rested on a very uneven surface of the schists, for at one place the molten rock, after traversing the conglomerate, has invaded a sill of hornblende schist and has carried with it rounded conglomerate pebbles.

Lorne.

(Mr. Symes

In the Old Red Sandstone basin of Lorne some interesting additions have been made to our knowledge during the past year by the work of the Survey. In the *Summary of Progress* for 1897 an account was given of the discovery of *Cephalaspis*, near Oban, whereby the sandstones, shales, and volcanic rocks of Lorne were definitely proved to be of the age of the Lower Old Red Sandstone. Further investigation has resulted in the discovery, by MR. SYMES, of another locality for fossil fishes, and in the finding, by MR. PEACH, of the best specimen that has yet been obtained from this region. This ichthyolitic band occurs on the mainland shore of Kerrera Sound, about three miles south from Oban, where grey fine-grained flags are seen intercalated

(Mr. Symes.) in the conglomerate on which the andesitic lavas rest. The fine ichthyolite referred to is an excellent example of the new species, *Cephalaspis lornensis*, showing the body and fins. It is now being figured by DR. TRAQUAIR, who in regard to the other fish-remains obtained by the collector, MR. TAIT, has been good enough to furnish the following note:—

(Dr. Traquair.)

> "The additional fish-remains from Oban collected by the Geologica Survey during the year 1898, though of great interest, are unfortunately not well enough preserved to justify their specific determination. Two forms new to the locality have occurred;—one is a small Acanthodian fish belonging to the genus *Mesacanthus* and closely resembling the *M. Mitchelli*, Eg., of the Forfarshire beds; the other is a small fragment of what may turn out to be a new species of *Thelodus*."

MESSRS. PEACH and SYMES also noticed plant-remains in the same fish-bearing band, but the specimens were found by MR. KIDSTON to be too indistinct for satisfactory determination.

(Mr. Symes.) In prosecuting his survey, MR. SYMES has found that the deposit of sedimentary strata, which in the northern and western parts of the Lorne district intervenes between the base of the volcanic series and the underlying slates, reappears also in the south, where it has not hitherto been shown on published maps. About two miles N.N.E. of Kilmelfort a good section may be seen of these sediments. From under the horizontal sheets of lava the conglomerate emerges as a vertical wall, about 100 feet high, resting on vertical siliceous schists. Between the conglomerate and the bottom of the lavas there intervene about fifty feet of purplish flagstones, but without any apparent representative of the fossiliferous zone which elsewhere is found on this horizon. The blocks in the conglomerate are on the whole more angular than around Oban, and are varied in composition. Among them the following rocks were observed:—andesite, limestone, sandstone, calcareous sandstone, tuff, porphyritic epidiorite, garnet-schist, and quartzite, but no granite. Occasional thin beds of sedimentary material occur in this thick mass of coarse detritus, but they are not constant.

In the district round Oban a number of thin beds of purplish shales, sandstones, and fine conglomerate were found intercalated with the andesite sheets at different horizons. One, only a few feet thick, was traced in the Glen Lonan valley, about 500 feet above sea-level; another was met with on the road to Loch Nell, close to Baligoun, made up of thin shales, and small water-worn pebbles of quartz; while in the Feochan valley, four miles S.E. of Oban, three outcrops of shales were mapped.

On the east side of Eilean nan Caorach, which is N.W. of Easdale, the andesites are found resting on tuff close to the water edge, and below the tuff lie red, green, and purple shales, and thin conglomerate. Again, at the base of the cliff, in the amphitheatre known as Sloc ant Sisnian, about half-a-mile north of Easdale village, two small exposures of red and grey shales dipping N.W. at 20°, and traversed by numerous basalt dykes, were detected underneath the volcanic series. Similar strata appear below the andesites at Ardetallan on the north shore of

Loch Feochan, where they include hard greenish grits which were formerly worked extensively for building purposes. The quarry had to be abandoned because, as the surface was only 25 feet above high-water mark the excavations were flooded when they reached sea-level. This quarry, and one at Barnacarry, on the south of Loch Feochan, are the only quarries of the same material in the whole district. (Mr. Symes.

The conglomerate in the Dunollie grounds at Oban contains much more matrix than the same deposit further south. It has been subjected to so much compression and dislocation that its great andesite blocks are all crushed and broken up.

In the railway cutting near Oban, and at the locality on the Sound of Kerrera already referred to, the fossiliferous band lies only about fifty feet above the black shales of the metamorphic series. The conglomerate which emerges from underneath this band is somewhat different from that of the conspicuous cliffs near Oban, inasmuch as its blocks are only about half the size, are enclosed in a less proportion of cementing material, and include a much larger percentage of quartzite fragments.

A large part of the area surveyed by MR. SYMES last year has lain among the volcanic rocks of the Lower Old Red Sandstone, which form so conspicuous a feature in the geology of the district of Lorne. He has now extended his survey to the southern margin of the volcanic area, where the lavas terminate as usual in a line of picturesque cliff crowning a talus slope that descends to the surrounding lower ground. No special petrographical distinction was observed in the characteristics of the lavas in the southern part of the region. No tuffs have yet been noticed among them.

East from Oban the observer ascends over the andesite sheets until he reaches an horizon of tuff which lies about 400 feet above the base of the lavas. Above this platform of pyroclastic material another series of lava-flows is met with which stretches for some twelve miles east of Oban. It is difficult, however, to follow the true stratigraphical succession, and to estimate the real thickness of the volcanic series, for the whole country is broken up by numerous N.N.E. faults which not impossibly repeat the beds. But assuming that the volcanic rocks about Taynuilt are higher than those to the west of them we can observe a decided petrological change in the character of the lavas that occur about two miles to the north-west of Taynuilt at Airds Park. The sheets there exposed are of a more acid type than that of the usual Lorne andesites. They weather into a purplish-red, and show a finely-banded rhyolitic structure. Not improbably they lie on the same horizon as those recorded by MR. KYNASTON from the Glen Nant Valley (*Summary of Progress* for 1897, p. 84).

Cracks filled up with hardened sandstone are frequent all through the andesitic sheets, and are in every respect similar to those which have now been observed so commonly among the lavas of the Lower Old Red Sandstone. The sandy silt has been

Mr. Symes.) washed into fissures and cavernous hollows of the cooled lava, and where these spaces have run along the middle of a single sheet they sometimes present a deceptive resemblance to ordinary sedimentary intercalations that separate distinct flows of lava. Thus the seam of sediment eight inches thick, referred to in the *Report* for 1896 (p. 55) as intercalated between two lavas west of Connel Railway Station, has proved on subsequent examination to be only a portion of one of these sand-filled rents in the andesite.

The tuffs which cover so large an area on the north side of Loch Etive have been traced on the south side of the loch in a S.S.W. direction from the sea-level at Ach-na-cloich Railway Station to the high ground overlooking Glen Lonan where they appear to die out. Over part of this ground they form a striking feature in the landscape, for their outcrop terminates in an almost continuous vertical wall, like a great sill, which is broken in places by faults whereby portions of the cliff have been displaced.

Director General.) The DIRECTOR GENERAL, during his inspection of MR. SYMES' ground last summer, made the following field-notes on the sections of tuff to be seen near Ach-na-cloich. "In the grounds south of the Railway, exposures of a pink porphyritic rock occur, which might easily be taken for a felsite or felspar-porphyry. It has a dull, compact, felsitic matrix which when fresh takes a streak of steel. Through the matrix are scattered abundant pink felspars and a smaller proportion of much decayed mica. No free quartz was detected. Most of the felspar looks like orthoclase, but there may be some striated felspars also. From the few exposures here, one might naturally class the rock provisionally as probably an intrusive orthoclase-porphyry or somewhat altered trachyte, so far at least as its characters can be judged of in the field. It no doubt belongs to the same group as the 'crystal-tuff' observed further to the south-east by MR. KYNASTON (*Report* for 1896, p. 54)

"But a little to the west, in the railway cutting, a section is laid bare of a similar rock which unquestionably forms part of a series of tuffs, of which the true pyroclastic nature is made evident by their abundant lapilli. These tuffs present a fine-grained pinkish felsitic-looking matrix through which are abundantly scattered crystals of pink felspar and flakes of biotite. The felspars are sometimes striated and are generally remarkably fresh. Here and there a felspar crystal may be seen having a dull worn outer surface as if it had undergone some attrition or solution before being enveloped in the matrix. These crystals seem to have been ejected as loose lapilli from the explosion of some felspar-porphyry. The larger lapilli are angular fragments of dull felsitic-like material. The tuffs are distinctly bedded and consist of finer and coarser detritus. During the short time spent in their examination they yielded no fragment of the ordinary andesite, nor were they found to contain layers of sandstone or shale or any appreciable admixture of ordinary non-volcanic detritus. They seem to point to volcanic explosions of a nature

quite distinct from that of the Oban lavas, when a magma of a more acid composition, like that of a trachyte or rhyolite was blown into dust. (Director General.)

"Immediately below the tuffs on the north side of the railway cutting an andesite appears of the usual dull green compact type. It includes nests and veins of shaly sandstone, the stratification of which coincides with the dip of the andesite and of the tuffs. It also contains patches of tuff which show small lapilli of highly though minutely vesicular andesite. This tuff has probably fallen into hollows and rents of the lava. It is quite different from the orthophyre-looking or trachytic tuffs above."

Thin beds of compact brick-red tuff dipping east at 15° to 30° are interposed between the andesite sheets near Benbeg, two miles south of Connel. In the railway cutting a mile and a half east of Oban similar tuffs were met with lying on intercalated shales and dipping east at 5°. On Eilean-nan-Caorach brick-red tuffs were found at low-water-mark lying on similar strata. These tuffs, however, appear to have no connection in age or composition with the great mass that lies to the north and south of Loch Etive. A considerable thickness of tuff has been noticed on the high ground a mile and a half to the north of Easdale village, lying on the lavas, and, like these, dipping at about 20° to N.W. On the shore of Loch Feochan, a mile west of Glenfeochan, an agglomerate has been laid bare composed entirely of fragments of andesite. On the north shore of Loch Etive, near the Manse, a similar rock is capped with a lava sheet which has cracked so much in cooling that it looks as if it were composed of subangular blocks cemented together by sedimentary material. Highly micaceous sand has during the cooling of the lava been washed abundantly into its fissures. (Mr. Symes.

Some of the masses of agglomerate now referred to may possibly mark the positions of volcanic necks. But, so far as the mapping has yet gone there has been a singular absence of evidence of the orifices from which the volcanic materials were ejected.

In the *Summary of Progress* for 1897 (p. 64) reference was made to an interesting discovery by MR. WILKINSON of a volcanic mass at Glas Eilean, a small islet off the Jura shore at the southern entrance to the Sound of Islay. During the past summer the DIRECTOR GENERAL landed on this islet, and obtained confirmatory evidence that the rocks which form it belong to the same Lower Old Red Sandstone series as the lavas of Lorne. The rocks appear to consist chiefly of purplish-grey amygdaloidal andesites and decayed basalts. They show abundantly a true slaggy structure, their vesicles being commonly filled with calcite. A conspicuous feature among them links them with the volcanic series of Lorne and of the Lower Old Red Sandstone of central Scotland, viz., the abundance of veinings and irregular layers and nests of pale and red fine sandstone. Some parts of the lava have been entirely broken up into masses of slag, between which the sandy sediment has accumulated, precisely as may be seen Sound of Islay. (Director General.)

Sound of Islay. (Director General.)

on the coast-sections at the Red Head of Forfarshire, Turnberry Point in Ayrshire, and many sections round Oban.

The lavas of this islet occur in successive sheets, dipping towards the Sound at perhaps as much as 30° to 40°. They are separated by grassy hollows, some of which may conceal bands of tuff or ordinary sedimentary material. There can hardly be any doubt that Glas Eilean is a fragment of a volcanic series of the age of the Lower Old Red Sandstone. It lies nearly forty miles to the north of the rocks of that period in Arran and Cantyre, and fifty miles south from the volcanic masses of Oban. It not improbably marks the site of a distinct volcanic area about half way between that of Lorne and that of the Clyde.

Lorne volcanic series. (Mr. Kynaston.)

During the past year Mr. KYNASTON has completed the survey of the volcanic series between the rivers Awe and Nant. Nothing exceptional has been noticed by him in the course of the mapping. The same types of rock which have been fully described by him in former *Annual Reports* continue to prevail in the ground more recently traversed. It may be mentioned, however, that he met with an excellent exposure of the nodular variety of the more acid (rhyolitic) type of the lavas near Taynuilt. The nodular structure is there exhibited in great perfection, some of the larger nodules measuring more than an inch in diameter.

In the *Annual Report* for 1896 reference was made to a small patch of sedimentary rocks, long ago noticed by MACCULLOCH, which occurs at the Pass of Brander, but the stratigraphical position of which was uncertain. In the *Summary of Progress* for 1897, in further allusion to these strata, it was mentioned that MR. KYNASTON believed them to be interstratified with the Lorne andesites, and thus to be part of the Lower Old Red Sandstone. It was stated at the same time that though they had hitherto proved devoid of organic remains, their more shaly parts might prove to be fossiliferous. They were accordingly searched last year by the fossil collector, MR. TAIT, who succeeded in obtaining a collection of plants which leaves no doubt that the strata in question are of Carboniferous age. A fuller account of them in their interesting bearing on the geological history of the West Highlands will therefore be given in the section on the Carboniferous system in later pages of the present volume (p. 129).

Granites of Ben Cruachan and Glen Etive.

(Mr. Kynaston.)

In continuation of his field-work reported in the *Summary of Progress* for 1897, MR. KYNASTON has pushed the mapping still further across the districts of Ben Cruachan and Glen Etive. He has surveyed considerable tracts of eruptive rock, and has devoted special attention to the phenomena of contact metamorphism around these tracts. The effects of the Ben Cruachan granite on the surrounding rocks were recognised by MR. HILL in 1893, when he traced the comparatively unaltered limestones and phyllites of the Loch Awe series across the Pass of Brander

into the neighbourhood of the granite. Mr. KYNASTON having now mapped the ground around the granite, has supplied the following digest of the chief results of his work:— (Mr. Kynaston.)

1. *Ben Cruachan District.*—In this area MR. KYNASTON has completed the mapping of the altered rocks and diorites of Ben-a-Bhuridh and the eastern spurs of Ben Cruachan, situated to the west and north-west of Loch Awe Hotel. Reference was made in the *Summary of Progress* for 1897 (p. 86) to the diorite of Ben-a-Bhuridh, and last year further specimens of these rocks were submitted to MR. TEALL. The rock is decidedly more basic than the normal type of Ben Cruachan, and closely resembles the dioritic varieties found among the granitic intrusions of the Southern Uplands. At the quarries, about a mile north of Loch Awe Station, the rock consists of a coarse-grained, massive quartz-diorite, not unlike some of the grey varieties of Ben Cruachan and Bonawe. Under the microscope, zoned plagioclase (oligoclase-andesine), biotite, hornblende, and interstitial quartz are seen, while apatite, sphene, epidote, and iron-ores occur as accessories. Passing from here to the crags on the northern ridge of Monadh Driseag, and to the eastern and southern slopes of Ben-a-Bhuridh we find the rock becoming darker in colour, more basic, and generally rather finer-grained. A specimen from the south side of Ben-a-Bhuridh shows, under the microscope, idiomorphic plagioclase, brown hornblende, biotite, interstitial quartz and micropegmatite, the two latter constituents appearing only in very small quantity; magnetite and apatite occur as accessories. The distribution of the diorite in this area is especially worthy of notice. It distinctly forms a belt or zone varying from about $\frac{1}{8}$ to $\frac{1}{4}$ mile in breadth, along the southern boundary of a large inclusion of altered epidiorite. This inclusion constitutes a large elongated mass, which forms the whole of the highest portions of Ben-a-Bhuridh, running east and west, and then bending round in a north-easterly direction across Coire Creachan and Allt Mhoile. It is more than three miles in length, and attains a maximum breadth on Ben-a-Bhuridh of about half-a-mile. The zone of diorite, however, is only found along its southern and south-eastern boundaries; along the line of contact on its northern and north-western sides, the more *acid* type of the main mass of the Cruachan granite makes its appearance. The question naturally arises: Why should this dioritic modification of the granite occur in such close association with this included mass of epidiorite. It is certainly difficult to explain except on the supposition that an inter-action of some kind has taken place between the epidiorite and the intrusive rock, but if so, why does the granite show no modification of this kind on the opposite side of the epidiorite? Lacroix, in his valuable paper on the Granites of the Pyrenees,* has described numerous cases of basic modifications in the granite, which he attributes to endomorphic action between the

* Lacroix. "Le Granite des Pyrénées et ses phénomènes de contact." —*Bull. des Services de la Carte géologique de la France.* No. 64. 1898.

granite and limestone, acting within the granite magma, and he describes aureoles of endomorphosed granite (diorite, &c.) around included patches of calcareous sediment. It is perhaps possible that something of the same kind may occur here, and the peculiar zone of the Ben-a-Bhuridh diorite may be compared to the peripheral zones of hornblendic rock round included patches of limestone in the Pyrenees. It is possible that the exact conditions requisite for the assimilation of more basic material did not obtain on the northern side of the epidiorite inclusion. While mapping the northern and north-western boundary of the epidiorite, MR. KYNASTON noticed numerous strips of quartzose sediment, sometimes at the actual contact with the granite, sometimes folded in with the epidiorite, and the latter rock itself is here far less rich in hornblendic material than towards its southern margin; in fact, in many places, as at Lairig Torran, in the crags above Allt Mhoile, and in the Allt Mhoile burn, the rock shows little or no hornblende to the naked eye. It is grey and gneissose, with indications of porphyritic felspar. This, however, no doubt, merely represents a variety of the original epidiorite sill, and we know that considerable variation is an exceedingly common feature of the epidiorites of the Loch Awe and neighbouring areas. This, then, may very possibly be an explanation why no dioritic modification of the granite is found on the northern side of the Ben-a-Bhuridh inclusion. On the one side, the southern, where, until a better explanation offers itself, it may be assumed that basic material has been assimilated by the granite magma, we have an epidiorite very rich in hornblende, while on the other side a highly felspathic rock occurs with bands of quartzose sediment, which would not so readily lend themselves to any such endomorphic action. Further reference will be made in later pages to these epidiorites in connection with the contact metamorphism round the Cruachan granite.

2. *Glen Etive District.*—The mapping of the granite of the Black Mount deer-forest was continued this year from Glen Etive. At the same time a considerable area of granite and metamorphic rocks was mapped on the western side of Glen Etive, and on the higher ground and passes forming the watershed between Glen Etive and Glen Creran. In previous *Reports*, descriptions have been given of the Glen Etive type of granite from the area bounding Loch Etive and Glen Kinglass, and MR. KYNASTON'S opinion has been stated that the coarse and more acid Glen Etive rock is slightly later than that of Ben Cruachan, though belonging to the same geological period. The mapping of the Glen Etive area has fully confirmed this inference. The Glen Etive granite appears to constitute a large roughly oval-shaped mass, and this body of coarse and more acid material seems to form a huge core or plug within a slightly more basic and rather variable granite, of which the hornblende-granitite of Ben Cruachan may be taken as the type. The Cruachan type, then, forms a great, outer, encircling belt to the Glen Etive type. On passing from the former type to the latter, we notice an

abrupt change from a medium-grained rock, often rich in hornblende and plagioclase, to a very coarse and conspicuously porphyritic type of granite, in which the hornblende is greatly diminished, while quartz is frequently conspicuous. The difference between the two granites is further brought out in the slightly different types of scenery which has resulted from differences of weathering and disintegration in the two masses. (Mr. Kynaston.)

To the west of the head of Loch Etive the boundary line between the two granites runs along the eastern flanks of Ben Sguliaird and round to the north side of Airidh nan Lochan, at the head of Glen Ure. Here, however, they do not seem to be separated by a very hard-and-fast line, but a rather gradual passage may be traced from the one type to the other. The quartz of the coarse porphyritic type decreases, while the hornblende increases, and sometimes the large porphyritic felspars of the Glen Etive type seem to pass over into the more hornblendic type. In fact, in this neighbourhood the two granites are scarcely distinguishable over a belt of perhaps twenty yards or so; while elsewhere, as a rule, a sharp line can easily be distinguished between them with the naked eye. From the head of Glen Ure the boundary-line may be followed to the upper part of Allt Bhiorain, whence it trends more to the east, keeping for some way parallel with the northern side of the burn. Thence it curves round slightly to the north-east, passes north of Creag Dubh, and crosses the river Etive close to the schoolhouse. On the eastern side of the river it is easily carried in an almost due easterly direction up Glen Ceitlein, bearing round to the south-east, up to the col between Meall Odhar and Meall nan Eun, whence it probably runs in a general southerly direction to join the boundary line, already traced, in Glen Kinglass. As far as the mapping has gone there is no contact between this granite and any sedimentary rock, nor does it contain any inclusions of such rock. It is entirely surrounded by the Cruachan type.

The coarsely porphyritic structure, which is everywhere so conspicuous at the margin, is, however, not a uniform feature. The porphyritic crystals gradually die out towards the inner portion of the mass, and thus the porphyritic structure is here merely a marginal feature. There is, in fact, a coarsely porphyritic marginal zone to the Glen Etive granite, varying from about a quarter of a mile to a mile in breadth. Within this zone lies a generally coarse, homogeneous, pinkish biotite-granite, with hornblende rather as an accessory than as a principal constituent. The rock often resembles the more acid pink variety of Ben Cruachan, and there are occasionally, as on Ben Starav, considerable variations in texture.

Specimens of the Glen Etive granite from the Glen Kinglass area, were examined under the microscope by MR. TEALL. The coarse variety of the biotite-granite from near Doire-nan-Saor was found to show zoned plagioclase, biotite, and interstitial alkali-felspar in large plates, while quartz is comparatively scarce. Hornblende, sphene, and iron ores are accessories. The interstitial felspar is often developed as microperthite.

Mr. Kynaston.) Other slices of the rock again show a good deal more quartz and sometimes rather less biotite, though on the whole only slight variation in composition is observable in this type of granite. Fine-grained varieties are found on Ben Starav, but the constituents are the same as in the coarser specimens. The alkali-felspar occasionally shows microcline structure. A fine-grained grey rock from Coire-nan-Lair, on the south side of Ben Starav, shows porphyritic or pseudo-porphyritic constituents in a finer-grained matrix. The larger constituents comprise zoned plagioclase, microperthite, quartz, and biotite, while the ground-mass is a micro-crystalline aggregate of quartz and felspar. Small veins and bands, fine-grained, and consisting mainly of quartz and felspar, are not uncommon in certain places. Coarse pegmatitic veins are also met with about Ben Starav and Ben Trilleachan.

The porphyrite dykes and sills, however, so numerous and characteristic in the Cruachan granite, are entirely absent in the Glen Etive mass. This would seem to imply that the Glen Etive granite is of later date, or perhaps of about the same date as the porphyrite intrusions. There are nevertheless in the neighbourhood of Ben Starav a few small basic dykes, with a general N.W. and S.E. trend, of a rather peculiar rock. Mr. Teall remarks that these dykes consist of rocks of a very unusual type. A specimen from Coire-nan-Lair, on the southern side of Ben Starav, shows under the microscope green pseudomorphs after olivine, idiomorphic augite (very abundant), brown basaltic hornblende, biotite (same colour as the hornblende), felspar (scarce), magnetite, and some undetermined interstitial matter. The rock is a kind of Hornblende-Basalt. Possibly it may be connected with some of the more basic modifications of the underlying magma, which here and there may have made their way to the surface during the later dyke-forming phase. Thus, in the Kilchrenan area, one of the later sills consists, not only of the normal porphyrite, but also of a basic modification (*Summary of Progress* for 1897, p. 60) which consists of phenocrysts of brown hornblende, plagioclase, and malacolite, in a ground-mass of lath-shaped plagioclases, chlorite, and iron-ores. There are also one or two sills on Ben Duirinnis, above the Bonawe quarries, consisting of a rock allied to the camptonites, a specimen showing under the microscope large aggregates of hornblende crystals in a ground-mass of hornblende needles, felspar, and iron-ores. The small basic dykes in the Glen Etive area may possibly represent the final stage of the igneous activity of the district, after the divergent differentiation had proceeded to its final extent in the magma which constituted the source of supply of the various intrusive rocks.

The granite of the Ben Cruachan type is everywhere well-developed in the Glen Etive area outside the inner Glen Etive mass. There is not much more to be said concerning its mineralogical characters, beyond what is already known from the more typical region of Ben Cruachan itself. Occasionally it has a slightly foliated structure along its line of contact with the

Glen Etive mass, but this is not nearly so well shown as in Glen Kinglass (*Op. cit.*, p. 91). Sometimes the pink and more acid variety is well exposed, as along the ridge of Ben Sguliaird, where the rock is identical with that composing the upper portion of Ben Cruachan itself, and again about the summit of Meall Odhar, while sometimes, and perhaps more frequently, the more hornblendic variety predominates, and the rock, as at Bonawe, partakes rather of the character of a quartz-diorite. (Mr. Kynaston.)

Diorites, of rather more basic character, occasionally occur as sill-like intrusions among the schists outside the granite area, and similar rocks have already been noticed near Glen Kinglass (*Op. cit.*, p. 92). A specimen from Coire Cercail, on the west side of Glen Etive, is a coarse-grained rock, almost entirely composed of hornblende. Under the microscope large individuals of hornblende are seen, which mutually interfere, together with a small quantity of turbid felspar. Apatite is more abundant and occurs in larger individuals than in the diorites of the main mass. The Glen Kinglass rocks of this type, classed rather as augite-diorites, show large individuals of pale augite partially replaced by green hornblende, biotite, and more or less idiomorphic zoned plagioclase. Occasionally, too, there is some interstitial alkali-felspar and quartz.

The later sill-like intrusions of *Porphyrite* are exceedingly numerous in the Cruachan type of granite, and in the surrounding schists throughout the Glen Etive area. They are identical in character with those already described in previous *Reports* from other areas further south, and they maintain the same general trend.

The outer boundary-line of the granite, where it comes in contact with the altered schists, is sometimes simple and well defined, but frequently, on the other hand, it is exceedingly complex, the marginal portion being inextricably mixed up with numerous broken-up strips and fragments of sedimentary material. In the neighbourhood of Beinn Fhionnlaidh, to the west of Glen Etive, a rock frequently appears, which consists of an intimate mixture of altered schist and granite, some parts presenting a profusion of small elongated fragments of schist embedded in a granitic matrix. Sometimes, too, where the granite is in contact with quartzite, numerous small fragments of quartzite are distributed freely and closely in the marginal portion of the granite. The fragments, however, are always angular and sharply defined, and show no signs of partial digestion by the granitic magma. The great number of inclusions of all sizes of altered schist in this area forms a striking feature of the Cruachan type of granite. The mode of intrusion of the granite may have partaken somewhat of the nature of a gigantic sill, the granitic paste forcing its way under pressure along the cleavage planes of the sediments, breaking them up, and flowing round the detached fragments.

In connection with the dykes and sills, mention should be made of a rather unusual type of quartz-porphyry, which occurs in the Cruachan granite at Bealach Odhar, about three miles

nas- east of Loch Etive head. It contains large pink felspars, up to an inch in length, smaller white felspars, lath-shaped hornblendes, some biotite, and small grains of quartz, in a rather compact, pinkish felspathic matrix. Now this rock is exactly what we should expect if a portion of the magma which consolidated as the coarse Glen Etive type of granite had been intruded into a fissure to form a dyke or sill. The porphyritic minerals of the sill have such close relationships to those constituting the primary constituents of the Glen Etive granite, that the conclusion can hardly be avoided that both rocks were directly derived from the same homogeneous magma, or "sub-magma" of the general source of supply. The sill in question is very near the margin of the Glen Etive granite, (about half a mile from it,) and is perhaps an apophysis of the main mass. Close relationships may also be observed between this sill and the normal porphyrites, which are numerous in this neighbourhood, but the relationships are rather those which have already been noticed as holding between the Glen Etive and Cruachan granites. Taking these relationships and other facts into consideration, MR. KYNASTON is of opinion that the period of intrusion of the Glen Etive granite would correspond to the latter portion of the dyke- or sill-forming phase of the various intrusions. Thus the chronological order would be:—

1. Ben Cruachan *Granite.*
2. *Porphyrite* dykes and sills.
3. Glen Etive *Granite* and *Quartz-Porphyry* dykes and sills.

CONTACT METAMORPHISM AROUND THE BEN CRUACHAN GRANITE.—Reference has been made in previous pages to the alteration of the surrounding rocks which has accompanied the intrusion of some of the younger granites of the Highlands. The huge granitic mass of Ben Cruachan affords special facilities for the study of the phenomena of contact-metamorphism, for not only does it contain an enormous body of eruptive material, but the Dalradian sedimentary formation around it had undergone so little alteration before it invaded them that its effects upon them can be satisfactorily studied over a wide area. Some of MR. KYNASTON'S observations on this interesting subject have appeared in previous *Reports*, but his work last year has led him into a more extensive examination of the influence of the granite, as explained in the following digest:—

1. *Loch Awe district, Ben-a-Bhuridh, and the south-eastern end of the Pass of Brander.*—In this area certain members of the "Loch Awe Series," on being traced up to their contact with the granite are found to have undergone considerable contact-metamorphism. The degree of alteration increases towards the granite in such a manner as to leave no doubt that it has been caused by the direct action of the granitic intrusion. The sedimentary rocks here exposed may be conveniently divided into the following groups, though no hard-and-fast line can be drawn between any of them:—

(1.) The *banded calcareous series*, of the south-east end of the Pass of Brander. These rocks are especially well

seen in the neighbourhood of the Falls of Cruachan. Occasionally good bands of pure limestone are intercalated among them. (Mr. Kynaston.)

(2.) The *black schists*, of the south and south-eastern slopes of Ben-a-Bhuridh,

(3.) *Quartzose schists, gritty beds*, and *quartzites*, of the eastern portion of Ben-a-Bhuridh, and Monadh-Driseag. Calcareous beds may appear in either of the last two series, and black-schists are frequently intercalated with the more quartzose beds.

A short account of the metamorphic phenomena in the neighbourhood of Bonawe, where fairly similar rocks to those of Ben-a-Bhuridh also occur, was given in the last *Summary of Progress*, and special attention was there called to the cordierite-bearing hornfels.* In the Loch Awe area a large number of specimens of altered rocks at, and at various distances from, the granite contact, was collected by MR. KYNASTON. These were submitted for microscopic examination to MR. TEALL, who has furnished the following report on the banded calcareous series, and the cordierite-bearing rocks, which occur in this area also:—

"The rocks of the '*banded calcareous series*' were evidently fine-grained sedimentary rocks, in which the relative proportions of argillaceous, arenaceous, and calcareous material were liable to repeated variations. Subsequent to their formation they must have been folded and cleaved, so that the original laminæ of arenaceous and calcareous material were more or less broken up into lenticular folia. Sometimes the different types of sediment were, as it were, kneaded together without the development of any well-defined parallel structure. This, however, only applies to small portions of the specimens. Strain-slip cleavage is often recognisable in the dark bands. The contact action appears to have been subsequent to the movement, and to have destroyed to a great extent the schistosity produced by it. (Mr. Teall on Banded Calcareous Series.)

"The rocks are now fine-grained or compact, and consist of thin alternating folia, of a dark purplish, and pale grey, greenish, or yellowish colour. The dark folia represent the more argillaceous laminæ of the original sediment. They are now largely composed of a confused aggregate of micaceous and chloritic minerals, amongst which the characteristic brown mica may be observed. In one or two specimens small albites occur, as they do in some of the albite-schists; but it may be doubted whether this mineral is due to contact action.

"The light-coloured folia represent in most cases the more calcareous laminæ of the original sediments. They are rich in minerals of the type usually occurring in impure limestones which have been subjected to contact action. A colourless or pale-green pyroxene, and a colourless garnet are the two most characteristic minerals, but epidote and hornblende also occur. The pyroxene is usually present in small grains, and only occasionally attains dimensions large enough to show characteristic cleavages and optic properties. Under these circumstances,

* *Op. cit.*, p. 89.

it is not always easy, in the absence of colour, to distinguish the pyroxene from a mineral of the epidote-zoisite group.

"Where carbonates have been preserved, which, however, is rarely the case, a narrow zone of granular pyroxene may be frequently seen separating them from quartz. The garnet is colourless, and often shows the anomalous double-refraction of grossularite. Like the pyroxene, it forms narrow zones round a carbonate, with respect to which it is idiomorphic.

"In some rocks [*e.g.* 8238] epidote takes the place of pyroxene, and the pale yellow folia are then formed of epidosite,—a rock composed of epidote and quartz. One or two specimens contain large crystals of apatite, which appear to have been developed *in situ*, for they are too large to be regarded as original clastic constituents. Sphene is sometimes an important accessory, and is often deeply coloured and idiomorphic. The other minerals, of which quartz and hornblende are the most important, do not call for special notice.

"One specimen belonging to this group [8251] is of exceptional interest.* It is a rock of compound origin, consisting of igneous and sedimentary material most intimately interblended. Thin folia, largely composed of granitic material, may be seen traversing the banded hornfels of the normal type, parallel to the banding. But there is no sharp line of demarcation between the two, although the granitic folia are coarser in grain than those which consist of sedimentary material. Under the microscope the interblending of the two kinds of material is very obvious. To the granite must be referred orthoclase, oligoclase, biotite in large plates, and some of the quartz; to the sedimentary rock, biotite in minute scales and aggregates, granular pyroxene, and the remainder of the quartz. The sphene and hornblende probably also belong mainly to the sedimentary rock. It is especially worthy of note that, although the granitic folia are only two or three millimetres in breadth, the individuals are as large as those occurring in ordinary granite (1 or 2 mms.). This clearly shows that the whole rock must have been subjected to the physical conditions under which the granite consolidated. The granitic invasion has clearly followed by preference the calcareous folia, for the granular pyroxene occurs abundantly as inclusions in all the granitic minerals except the biotite, whereas the dark purplish bands of biotite-hornfels retain their normal character, and do not show the same tendency to blend with the granitic constituents.

"That a granitic magma should possess the power of eating up limestone we can well understand, but it is doubtful whether that power can be appealed to in the present case as an explanation of the facts above referred to, for the granitic magma does not appear to have changed its composition. It is now represented by the same minerals as those of normal granite, and

* This specimen was obtained at the granite contact from the ridge due east of the Cruachan burn.

the pyroxene of the calc-silicate-hornfels merely occurs as inclusions in these granitic minerals. There is, therefore, direct evidence that the lime has never been incorporated in the magma. Seeing, however, that the granite of the district is associated with quartz-diorites and basic diorites, it becomes important to ascertain whether these rocks may be due to the absorption of sedimentary rocks. (Mr. Teall on Banded Calcareous Series.)

"In any case, we are here dealing with a rock of compound origin. It is neither an igneous rock nor a sedimentary rock, but a mixture of the two.

"Attention was directed to the existence of such rocks many years ago by M. MICHEL LEVY,* who recognised two types. In the one the granitic material has been so to speak superposed upon the sedimentary rock, so that the contact materials float in a granitic matrix (superposition). In the other type the injection has taken place between the folia (injection "lit par lit"). Both these types are represented in this specimen. The granitic material has penetrated the sedimentary rock between the thin bands of biotite-hornfels, and has, moreover, superposed itself to some extent upon the bands of calc-silicate-hornfels, so that the contact-pyroxene occurs as inclusions in the orthoclase, oligoclase, and quartz of the granite."

PROFESSOR LACROIX, to whose observations on the granite of the Pyrenees reference has already been made in connexion with the diorite of Ben-a-Bhuridh, has also described cases in association with contact phenomena very similar to that now under consideration.† He describes passages between schists impregnated with granite, and granite impregnated with schist, and says that felspathisation of the schists has been caused (*a*) by imbibition, (*b*) by injection—*i.e.*, by granitic material injected between the laminæ (injection "lit par lit").

In the banded calcareous series of the Pass of Brander bands are frequently met with, sometimes a few feet in thickness, of more or less pure limestone. This material is found to be converted into a finely crystalline, nearly white or greyish marble (Cipolin). A specimen, one-sixth of a mile from the granite, from the ridge east of Cruachan Burn, is a crystalline granular aggregate of calcite, with some irregular grains of diopside, and a few flakes of mica.

The *Black Schists* are found near the granite to be altered into dark compact hornfels, in which quartzose lenticles are often present. Where arenaceous material has been interlaminated with argillaceous, a more or less compact hornfels has resulted with strongly-marked dark and pale, or sometimes reddish bands. A specimen of the altered black schist from the south side of Ben-a-Bhuridh, is a dark compact hornfels with quartzose lenticles. MR. TEALL reports that under the microscope, "the dark hornfels is seen to be thickly crowded with black opaque particles and (Mr. Teall on the Black Schists.)

* Sur les Schistes Micacés des Environs de Saint-Léon (Allier). *Bull. Soc. Geol. France*, 1881, pp. 181–196.

† Lacroix. *Op. cit.*, p. 8.

Mr. Teall on the Black Schists.)

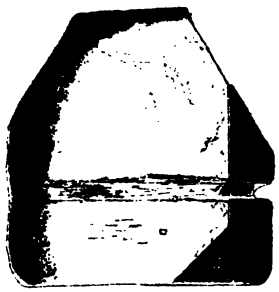
patches. The substratum in which these particles lie is crystalline, but the minerals are not easy to identify. Amongst them are two colourless minerals which differ markedly in their refractive indices, and one of which may be felspar. The quartzose lenticles are aggregates of quartz with films and patches of a pale coloured biotite often occurring in small scales. The distribution of these films shows that the rock was puckered, and in some cases the films may be traced as inclusions through comparatively large individuals of quartz, thus proving that to some extent at least the crystallisation was subsequent to the movement." MR. TEALL is inclined to think that the two doubtful minerals are felspar, and a pale biotite. If so, this would bring the rock into relation with the altered black schist of the Braemar (Glen Callater) area.

A dark, compact, banded hornfels, from the south side of the Pass of Brander, shows strain-slip cleavage, and was doubtless originally composed of alternating gritty and argillaceous layers. The former are now composed of quartz grains and minute scales of chloritic and micaceous minerals. The argillaceous layers are mainly composed of chloritic and micaceous minerals, amongst which brown mica may be recognised. The effect of the contact action has been to destroy to a great extent the previous schistosity of the rocks. Some reddish bands which occur in the hornfels of this type consist of a granulitic aggregate of quartz and turbid felspar, while epidote, zircon, and sphene occur as accessories. These bands probably represent laminæ of a fine-grained felspathic sandstone.

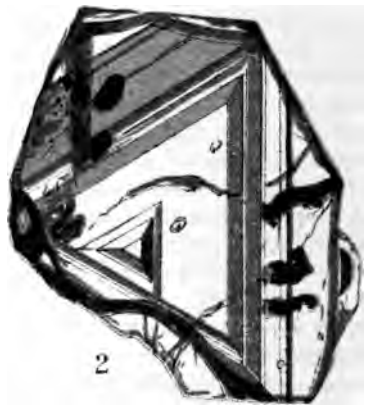
Mr. Teall on Cordierite Rocks containing Corundum.)

The *Cordierite-bearing rocks* which occur among the altered sediments (quartzose schists, biotite-hornfels, &c.,) of the eastern and northern portions of Monadh Driseag, at the back of Loch Awe Hotel, have been carefully studied by MR. TEALL who furnishes the following report regarding them:

"Another very interesting type of metamorphic rock, is characterised by the presence of cordierite. This type is represented by medium-grained, often bluish-grey, fairly massive rocks, of which a specimen from the north-east side of Monadh Driseag [8254] may be selected as a type. Under the microscope one sees an aggregate of colourless minerals, in which lie detached scales and nests of biotite, and patches crowded with small grains and imperfect crystals of a green spinelle. The colourless minerals are cordierite, alkali-felspar, and oligoclase. The individuals vary in size, often measuring one or two mms. across, but rarely show any trace of crystalline form. The cordierite contains biotite, often in minute rounded scales, spinelle, and zircon, as inclusions. It is difficult in an ordinary slide to distinguish in all cases the felspar from the cordierite, as both have approximately the same refractive and double-refractive power. The characteristic yellow pleochroic halos surrounding the zircons in the cordierite are then the most useful means of distinguishing between the two minerals. But if a thin slice be heated on platinum foil, a change is produced in the cordierite. The pleochroic halos disappear, and a faint yellow colour seen best in one position of the polariser



1



2

3

4

5

Corundum.

Wyman & Sons, Lt.d, Lith. 3764-3.99.

(Mr. Teall on Cordierite Rocks containing Corundum.)

is developed all over the mineral. This faint general pleochroism, produced by heating, is not so marked as that of the halos, but is sufficient to distinguish the cordierite from the felspar, which remains absolutely colourless. In this way it can be shown that half, or possibly even more than half of the entire rock is composed of cordierite. Of the felspars, orthoclase is the most abundant. Pyrite occurs in grains, and as irregular masses wedged in between the other constituents. Quartz has not been observed in the specimen selected as a type.

"The occurrence in a slide [8254] of this rock of one or two colourless grains with very high refractive and moderate double-refractive power, led to a search for *corundum*, which proved successful. The coarsely-powdered rock was treated for about forty-eight hours with hydrofluoric acid, and the residue boiled with nitric acid to remove the pyrite. As the microscope disclosed the presence of some corroded fragments of andalusite, the powder was placed in methylene-iodide of sp. gr. 3·315. The final residue was then found to consist of corundum, green spinelle, and one or two crystals of rutile. The corundum occurs in irregular grains and crystals up to ·3 mm. in diameter. The crystals show a tendency to a tabular form, with hexagonal outlines (*see* Plate I). Those which are lying flat on the slide, and which show this outline, appear dark under crossed nicols, and give as a rule a negative uniaxial figure. Parallel striations in three directions at right angles to the sides of the hexagon may frequently be observed. These are in most, if not in all cases, due to repeated alternations of the rhombohedral and basal planes, in which the latter usually predominate. In this way a stair-like termination to the hexagonal prism is often produced."

The crystals represented on Plate I. have been drawn by MR. GILBERT WILLIAMS direct from the microscope. No. 1 shows a crystal which is well developed on the right hand side. Faces of the hexagonal prism ($11\bar{2}0$), the primitive rhombohedron ($10\bar{1}1$), and the basal plane (0001) can be definitely recognised.

No. 2 illustrates, in a very perfect manner, the step-like arrangement on the basal plane due to the alternate development of this face and the faces of a rhombohedron. This grain contains inclusions of spinelle.

No. 3 is a flat crystal bounded by the faces of the prism and showing on its basal plane the well known rhombohedral striations, which are also seen in No. 5.

No. 4 represents one of the more irregular forms with rounded angles and transverse grooves. It is evidently a portion of a rude hexagonal prism.

"The forms observed are those of a hexagonal prism ($11\bar{2}0$), a rhombohedron ($10\bar{1}1$), and the basal pinacoid (0001)—a characteristic combination for corundum, and one commonly seen in the Burma rubies and Montana sapphires. The steep pyramidal planes, so characteristic of the Ceylon and Kashmir sapphires and the common corundums of Madras, have not been observed. Inclusions of green spinelle and cavities, usually irregular, but sometimes in the form of negative crystals, are not infrequent.

"Other specimens of the cordierite-hornfels differ from the type in the relative proportions of the different constituents, in the presence of quartz, sometimes considerably abundant, and

Mr. Teall on Cordierite Rocks containing Corundum.)

to a certain extent also in structure. One specimen [7618] is especially interesting as furnishing conclusive evidence as to the relative age of the crystallisation of the cordierite and the movements which have so powerfully affected the sedimentary rocks of the district. Apart from a few large patches of pyrite and flakes of biotite (·4 mm), this rock is composed of extremely minute opaque grains and plates (ilmenite ·01–·02 mm.) scattered through a granulitic aggregate of cordierite, quartz, andalusite, and felspar. Sometimes the grains of cordierite attain a considerable size, and then the section loses its granulitic character. Sericitic mica, zircon, and rutile occur as accessory constituents.

"The distribution of the minute opaque particles clearly shows that the rock was puckered with the occasional development of strain-slip cleavage, but this puckering has had no effect whatever on the cordierite, or on the other colourless constituents. All these in their present form have been clearly developed since the movement took place.

"This rock is interesting from another point of view. Puckering of the type here revealed is only known in phyllites and slates—that is, in rocks which were originally fine-grained sediments rich in argillaceous material. Out of such sediments the cordierite-bearing rocks have doubtless been formed, the alkali of the micaceous minerals going to form felspar, while some, or all, of the magnesia present combined with alumina and silica to form cordierite. The poverty of this rock in micaceous minerals, so common in the phyllites, is thus explained, and the simultaneous formation of cordierite and alkali-felspar is accounted for.

"In the *Explanation of Sheet 75* of the Geological Survey of Scotland (1896) a general account of the characters and distribution of the cordierite-bearing rocks of Scotland, so far as these were known at the time, was given. Since that date MR. BARROW has sent up another series from Sheet 65 (Aberdeen and Forfar). They present many points of resemblance to the rocks above described. There is the same association of cordierite, andalusite, biotite, and a green spinelle, with a variable amount of quartz and felspar; but the rocks are coarser in grain and always contain sillimanite, sometimes also garnet. One of these rocks [7085], containing cordierite, sillimanite, andalusite, felspar, biotite, ilmenite, and the green spinelle, was analysed, and the analysis is quoted as throwing light on the composition of the original sediment. It agrees remarkably with the analysis of a cordierite contact-rock from Monte Aviolo, described by SALOMON, which is quoted for comparison.

	I.		II.
SiO_2	42·08	...	44·62
TiO_2	2·16	...	2·04
Al_2O_3	32·40	...	33·33
Fe_2O_3	13·44	...	7·32
FeO		...	5·45
MgO	3·30	...	5·46
CaO	1·42	...	0·12
K_2O	2·20	...	0·68
Na_2O	1·60	...	0·53
Ignition	1·60	...	1·47
	100·20		101·02

I. Cordierite-gneiss, from the north end of Black Hill, Aberdeenshire. [TEALL.]

II. Cordierit-contactfels, Monte Aviolo. "Geologische und Petrographische Studien am Monte Aviolo," von W. SALOMON. *Zeit. Deutsch. Geol. Gesell.*, 1890, p. 502.

(Mr. Teal on Cordie Rocks cor taining Corundun

"The principal difference between the two analyses lies in the greater amount of alkali in the Scottish rock. But SALOMON states that his specimen was specially selected on account of its containing very little felspar and less biotite than the average rocks of the group; so that, if an average rock had been selected, the agreement might have been still closer.

"The close correspondence between the cordierite-bearing rocks of the Ben Cruachan area and those of Monte Aviolo is especially interesting, because in both cases the granitic rock is of the same type. It is a tonalite or quartz-mica-diorite, rather than a true granite.

"There is another point of some interest which deserves mention in this connection. In the *Explanation to Sheet 75* (Scotland) special attention was directed to a rock of compound origin belonging to this group [3693]. 'The igneous portion is represented by more or less idiomorphic oligoclase, biotite, micropoikilitic orthoclase, and quartz; the metamorphic portion by cordierite, quartz, biotite, sillimanite, and a green spinelle. The rock into which the granitic magma was intruded is now represented by somewhat ill-defined shreds, patches, and streaks, in a paste of igneous origin' (*l.c.*, p. 37). It is not possible to distinguish igneous from sedimentary material in the Ben Cruachan specimens, nevertheless something of the same kind as that above referred to may have taken place, especially as there is direct evidence that this has been the case with the bands of pyroxene-hornfels in the 'banded series.' We thus see that the cordierite-bearing contact-rocks, which always belong to the inner zones of contact metamorphism, and often occur at the actual junction, are peculiarly liable to be invaded by igneous material and more or less broken up. SALOMON describes inclusions of the cordierite rocks in the tonalite of Monte Aviolo, and concludes from the occurrence of garnets and large crystals of biotite in a zone surrounding these inclusions, that the composition of the tonalite-magma was modified by the absorption of some of the contact material.

"Under these circumstances it is particularly interesting to note that cordierite, in association with the same minerals—sillimanite, green spinelle, orthoclase, plagioclase, etc.—occurs frequently in the ejected blocks of the Laacher See*, and as inclusions in the andesites and less frequently in the trachytes of the Eifel and Siebengebirge†. Mineral aggregates of cordierite, andalusite, sillimanite, felspar, biotite, pleonaste, corundum, rutile, quartz, garnet, zircon, and magnetite, bearing the closest

* "Mikroskopische Untersuchung der aus krystallinischen Gesteinen herrührenden Auswürflinge des Laacher Sees"; von Carl Dittmar. *Verh. d. Naturh. Vereines.* Bonn. 1887, p. 499.

† Beiträge zur Kenntniss der Trachyt und Basaltgesteine des hohen Eifel. Carl Vogelsang. Zeit. deutsch. geol. Gesell. 1890, p. 1.

Mr. Teall (Cordierite rocks containing corundum.)

resemblance to the contact-rocks of Monte Aviolo and Ben Cruachan, occur as fragments and 'schlieren' in the hornblende-andesite of Bocksberg and Reugensfeld in the Eifel (Vogelsang). The fragments are usually rounded, but sometimes angular. They may attain a diameter of 6cms., while the 'schlieren' may be 10cms. in length. The larger fragments are often easily separable from the matrix, but the 'schlieren' may be most intimately blended with it. These inclusions vary in size, and are often so small as to be only recognisable under the microscope. It seems impossible to avoid the conclusion that we see in the process which goes on at the contact of plutonic rocks, the agency by which inclusions of the kind described by Vogelsang are introduced into igneous magmas and it is certainly remarkable, though possibly only an accidental coincidence, that the hornblende-andesites of the Eifel should be the volcanic representatives of a tonalite magma similar to that which formed the masses of Monte Aviolo and Ben Cruachan.

"This is not the place to enter upon a general discussion of the natural history of the cordierite-bearing rocks, but one or two remarks may perhaps be permitted. The mineral occurs in many igneous rocks such as granite, quartz-felsite (Cornwall), liparite, kersantite; and although in some of these it is clearly not the result of crystallisation from the normal igneous magma, in others it possesses all the characters of a mineral so formed. This, for example, is the case of the cordierite of the kersantite of Michaelstein in the Hartz, where it occurs in idiomorphic crystals. Nevertheless, a doubt is suggested as to whether, even in this case, it can be regarded as a mineral belonging to the igneous magma, for the rock in which it occurs contains numerous inclusions, made up of sillimanite, andalusite, kyanite, spinelle, and other minerals, usually associated with cordierite in contact rocks and crystalline schists. Moreover, the mineral itself contains spinelle as inclusions. It seems probable therefore that in some way or other the presence of cordierite in the kersantite of Michaelstein is due to the influence of the contact rocks upon the igneous magma, in which case it must be regarded as an endomorphic contact mineral.

"Apart from the somewhat rare and sporadic occurrence of cordierite in ejected blocks and igneous rocks, we find the mineral in crystalline schists of doubtful origin, and in contact-rocks. Its mode of origin in the latter case is fairly clear. It has been produced by the metamorphosis of sedimentary rocks, containing argillaceous material. The presence of 2 or 3 per cent. of magnesia is common in slates and shales, and as 3 per cent. of magnesia is sufficient to make about 30 per cent. of cordierite, when combined with silica, alumina, and iron, it is clear that rocks of this type furnish the necessary chemical conditions. Do these facts throw light on the origin of the crystalline schists containing cordierite—on the origin of the cordierite-gneisses? It is probable that they do, especially when taken in connection with the evidence of the tendency of the igneous magmas to

invade, and even impregnate, the rocks of the inner contact-zone. Suppose the phenomena of metamorphism, injection, and impregnation, which must have taken place round the Cruachan mass, to be intensified and accompanied by plastic deformation,— have we not then a rational explanation of the origin of many of the complex groups of crystalline schists which cannot be definitely classed as the metamorphosed representatives of either igneous or sedimentary rocks?"*

(Mr. Teal on Cordie Rocks con taining Corundum

Allusion has already been made to a large mass of epidiorite which MR. KYNASTON has found on the upper part of Ben-a-Bhuridh and in the corries to the north-east, as an inclusion within the granite. A general description of the rock was also given from his notes in the *Summary of Progress* for 1897 (pp. 90, 91). The exact degree of alteration which this epidiorite has undergone owing to the granite intrusion is very difficult to ascertain, owing to the great amount of variation in the rock-mass. Thus, along its southern and south-eastern borders it is exceedingly rich in hornblende, while towards the opposite margin it is extremely felspathic, often showing little or no hornblende to the naked eye.

The Epidi orites. (I Kynaston

In the crags above Allt Mhoile the sill is exposed as a grey, more or less foliated rock, with indications of porphyritic felspars. Under the microscope [8258] MR. TEALL has observed "a few large and more or less turbid phenocrysts of plagioclase, often with irregular borders, in a ground-mass of microcrystalline quartz, felspar, biotite, and iron-ores. There are also two or three patches of micropoikilitic hornblende." The rock is well exposed also in the Allt Mhoile burn as a grey, fine-grained gneissose schist. Under the microscope similar ill-defined phenocrysts of plagioclase are seen, as in the preceding specimen. The ground-mass consists of a granular aggregate of quartz, orthoclase, plagioclase, biotite, and hornblende, with sphene, iron-ores, and sometimes augite, as accessories. The augite occurs as cores in the patches of hornblende, which is compact and often micropoikilitic. One specimen has a vein-like portion running through it, which does not show under the microscope any sharp line of demarcation between the two types of rock, but contains a fair amount of orthoclase. This would suggest an admixture of granitic material.

Specimens were also examined by MR. TEALL from one of the small sills on the south side of Ben-a-Bhuridh, outside the main mass of the granite. About a mile from the contact with the granite, the rock is a normal foliated epidiorite, with epidote and chlorite, and shows no signs of contact-action. At a third of a mile from the granite-contact brown mica is very characteristic, and the rock is very hard and compact, but otherwise it does

* Since this account of the Argyllshire rocks was written an important paper by DR. MOROSEWICZ has appeared (Tschermak, *Min. Mitth.* vol. xviii. (1898), pp. 1-90 and 105-240), in which some of the conclusions expressed above are more or less anticipated and greatly strengthened by experimental research.

e Epidi-
tes. (Mr
naston.)

not differ markedly from many of the epidiorites of the neighbourhood. So far it has not been possible to procure actual contact specimens of any of these smaller sills.

2. *Glen Etive Area.*—The mapping of this area has not yet proceeded far enough to give any very conclusive results with regard to the behaviour of the sedimentary rocks outside the margin of the Cruachan type of granite. Specimens of the series of pinkish gneissic-looking rocks (*ante*, p. 79), from the upper portions of some of the burns draining the western side of Glen Etive, are described by MR. TEALL as fine-grained, grey, gneissose hornfels. Under the microscope, a slide is seen to consist of quartz, andalusite (micropoikilitic), white mica, biotite, and magnetite. One specimen [8269] contains cordierite.

A specimen of the garnetiferous mica-schist from Clach-nan-Meirleach, about half a mile from the granite, is described by MR. TEALL as a "schistose, micaceous hornfels, with large patches of biotite which sometimes lie across the foliation." Under the microscope, we see "quartz, biotite, white mica, and magnetite. The main mass of the rock is markedly foliated, but the folia sometimes wind round non-foliated patches composed of the same constituents, but with more magnetite. These patches are probably pseudomorphs after garnet." Occasionally [8271] these patches "enclose cores of unaltered garnet. It seems probable that the rock was originally a garnetiferous mica-schist, that the garnets were more or less decomposed, and that the rock was then subjected to contact metamorphism."

There is thus conclusive evidence of very decided contact-action, wherever the ground immediately bounding the Ben Cruachan type of granite has so far been examined. In the Pass of Brander, and the area bounding the eastern spurs of Ben Cruachan, this action is shown by MR. TEALL'S detailed researches to have been exceedingly intense. The sedimentary rocks may be followed from their comparatively unaltered condition, as in the neighbourhood of Kilchrenan and other parts of Lochaweside, into the various varieties of hornfels, some containing cordierite, of the Pass of Brander and slopes of Ben-a-Bhuridh. The hornfels-alteration of similar rocks with production of cordierite is again found to have taken place along the granite margin, in the neighbourhood of Bonawe, and along the western slopes of the Ben Duirinnis, on the north-west side of Loch Etive (*Summary of Progress* for 1897, p. 89), and a cordierite-hornfels has also been observed in the Glen Etive area. In this latter area, however, the contact-zone is not so well marked as it is further to the south-west, since evidently here the sediments had undergone the action of the forces of dynamic metamorphism to a far greater degree, and were already in the condition of highly crystalline schists previous to the intrusion of the granite. It is true that our knowledge of the district is by no means complete, so that it would be premature at present to enter into a discussion of the relative effects of the metamorphosing forces which have affected the rocks. Whatever these may have been, there can hardly be any doubt that the different varieties

of hornfels above described owe their peculiar and characteristic features directly to the contact-action which took place at the time of the intrusion of the Ben Cruachan granite. The Epidiorites (Mr. Kynaston)

Isle of Arran.

The remaining area of Old Red Sandstone mapped by the Geological Survey during the past year in Scotland lies in the island of Arran, where MR. GUNN has been engaged in continuation of the field-work described in previous *Annual Reports*. A belt of Old Red Sandstone sweeps across the centre of the island to the west coast. Near Dougrie on that side it seems all to belong to the lower division of the formation, characterised by thick bands of coarse quartzite-conglomerate, alternating with red and purple sandstones. The total thickness of these strata amounts to several thousand feet. The coarse conglomerates are unusually thick on the hill called Garbh Thorr, near Monyquil. Good exposures of the rock are to be seen in the old sea-cliffs south-east of Dougrie, where the beds dip south-south-west at high angles and are in places vertical. (Mr. Gunn

In the course of the field-work of last season MR. GUNN has made the discovery that near Auchencar this group of the Lower Old Red Sandstone includes a volcanic platform. He has traced a band of lava eastward for about two and a half miles, as far as to the north-west side of Garbh Thorr, and found it everywhere apparently underlying the main mass of the conglomerates, while the strata below it consist principally of sandstones. Where this lava appears at the surface it is largely amygdaloidal and of an andesitic character, though the lower part of it is in places compact and seems more basic than the rest. The best section has been cut by the Auchencar Burn about seventy yards east of the moor fence, where a thickness of from fifty to sixty feet of the volcanic material is exposed. The rock is amygdaloidal above and compact below. As the lava-sheet is nearly vertical it occupies but a narrow strip of ground, and, moreover, is a good deal concealed by drift. Still, traces of it may be detected in several places to the eastward, and unmistakable outcrops of it occur to the north of a conglomerate hill called Baniorlach, and likewise to the north-west of Garbh Thorr, where the band seems to be thicker than in the Auchencar Burn.

In the conglomerates above this volcanic zone pebbles of an andesitic rock, which have probably been derived from the lava, are common. Not improbably the volcanic material was extensively denuded before and during the formation of these conglomerates. The discovery of this band increases the number of the volcanic horizons in Arran to at least five: two in the Old Red Sandstone and three in the Carboniferous system; while to these must be added the great series of much younger (probably Tertiary) intrusive rocks.

South Wales.

[r.Cantrill.] In the re-survey of the South Wales coal-field portions of the surrounding tracts of Old Red Sandstone require to be mapped in order to complete the sheets of the one-inch map. During last year MR. CANTRILL was engaged upon this work in the district which extends from the valley of the Nêdd to that of the Twrch. Though it mainly lies on a dip-slope that drains southwards, this district includes the headwaters of the rivers Senni, Crai, and Sawdde, which rise on the north side of the escarpment of the Fans.

The lowest beds of the Old Red Sandstone which come to the surface in this area, consist of sandstones, shales, and marls, usually green, but occasionally dull-red, with green or red conglomeratic cornstones. They are exposed in Glyn Senni, Cwm Crai, and Blaen Tawe, while on Cefn Cûl some of the green sandstones have been quarried for roofing, paving, etc. The upper limit of these green strata is somewhat indefinite, and the series seems to belong rather to the upper arenaceous division of the Old Red Sandstone than to the lower part of that formation, in which red marls predominate. Above the green beds lies a great thickness of red sandstones, shales, and marls, with thin red calcareous bands at rare intervals. These strata form the great scarp of which Fan Gihirych, Fan Hir, and Fan Sir Gaer are prominent points. In their lower part they include some incoherent quartz-conglomerates, well seen near Llyn y Fan Fawr, while at about 50 feet from their top a pebbly grit runs near the top of the scarp of Fan Gihirych, and at the top of that of Fan Hir, where some of its pebbles are as large as hen's eggs. Conglomerates were first met with at this horizon in the Hepste valley (*Summary of Progress* for 1897, p. 95); the pebbles consist almost wholly of vein-quartz.

The highest subdivision of the Old Red Sandstone, the "grey grits and conglomerates," almost disappears a little west of the Tâf fawr, as previously reported, but in Cwm Byfre it is 24 feet thick, and it exists also in the valleys of the Haffes, Giedd, and Twrch. In Glyn Tawe and two other valleys further west it is clearly seen to be superimposed upon and not replaced by the red conglomerates described above. As has been mentioned in former *Annual Reports*, the strata of this subdivision resemble some quartz-conglomerates which are interstratified in the limestone, and therefore suggest a transition from the Old Red Sandstone into the Carboniferous system.

On the south side of the Coal-field MR. CANTRILL has mapped a small anticlinal tract of Old Red Sandstone on Stalling Down, east of Cowbridge, where red sandstones and grits, with quartz-pebbles, belonging to the upper part of the formation, are exposed.

DEVONIAN.

The re-survey of the counties of Devon and Cornwall has involved a re-examination of the Devonian rocks which are

restricted to that part of the United Kingdom. In Devonshire the stratigraphy of these rocks has been worked out by MR. USSHER as far as possible on a basis of palæontological evidence. But large areas in that county, and still more in Cornwall, have not yielded any organic remains, so that the geological position of the sedimentary rocks is by no means absolutely determined. On the published Survey maps the general body of strata has been coloured as Devonian, but it may be eventually possible to show that they include masses of much older date. In the meantime it is most convenient to keep the whole series under the old name until more precise information on the subject has been obtained.

Devon and Cornwall. (Mr. W. A. Ussher.)

MR. USSHER has prosecuted the revision of the western margin of Devonshire and the eastern borders of Cornwall, in the district between Princetown and Gunnislake. He has been engaged upon Upper Devonian slates, schalsteins, and "greenstones," together with tracts of Culm-measures and granite.

In this district the Upper Devonian strata consist of fine-grained slates normally of a pale greenish colour. They are traversed by planes of schistosity frequently horizontal and very seldom inclined at high angles. This tendency to horizontality in these planes is the rule throughout the ground to the west of Dartmoor. It is also apparent in the volcanic rocks and Culm-measures, in which the tendency to present more or less horizontal planes is due to the sharp, irregularly zig-zagged structure of the smaller folds. The bedding may therefore be in reality more or less vertical in the limbs of innumerable repeating folds which cannot be actually traced.

The Upper Devonian slates are exceedingly unfossiliferous; obscure organic remains were detected by MR. USSHER in only one or two places.

The relation of the Devonian slates to the volcanic rocks and Culm-measures, even where the rocks are visible at the surface, is obscured by faults, so that no actual succession can anywhere be obtained in the area recently surveyed. Within the aureole of metamorphism round the granite the lines of boundary between the several groups of rock are hardly capable of precise delineation. Viewing the evidence obtained from other districts, and taking what seems to be the most probable inference from the complex character of the Tavistock volcanic area, MR. USSHER is disposed to regard the volcanic rocks as most probably intermediate between the Upper Devonian formations and the Culm-measures. The earliest eruptions may have begun in the Upper Devonian period, but the main part of the volcanic history was probably contemporaneous with the lower portion of the Culm-measures.

The volcanic rocks of the Tavistock area consist of more or less vesicular schalsteins, the vesicles being often filled with calcite. With these bands a little compact greenish limestone is locally associated, apparently near the base of the series, as if the calcareous material represented Upper Devonian limestone, deposited in intervals between the earliest outflows of lava

Examples of this association of calcareous material are visible by the River Tavy, on the south side of Abbey Bridge, Tavistock, E. and by the side of the high road W.N.W. of Tavistock, near the second milestone at the turning to Langford. This point is of considerable interest, especially in connection with the origin of the curious and exceptional rock (2764) described by MR. TEALL (*Annual Report of the Geological Survey* for 1896, p. 52). That rock may perhaps have owed its origin and composition to the mingling of basic volcanic dust with calcareous detritus on the floor of the sea.

At and near Tavistock the association of hard dark, sometimes cherty Culm-measures with the volcanic rocks is so intimate as to suggest that lenticular patches of the one kind of rock have been interstratified in the other, but the zigzag bedding structure renders this supposition rather doubtful, for the effect might have been produced by the truncation of sharp plications. Be this as it may, there is every reason to conclude that the volcanic rocks with their associated dark basement Culm beds and schistose greenstones have been converted in part within the aureole of metamorphism round the granite into such types as have been described by MR. TEALL (Nos. 2762, 2763, and 2765 in the *Annual Report* above cited, p. 52).

Cox Tor Moor exhibits masses of altered greenstone (Gabbro) and varieties of the hard rocks mentioned in the same *Report* (p. 51). For these hard rocks and their different varieties it is proposed to employ the term "Peak Hill rocks," as they form that summit on the border of Dartmoor near Dousland. Although they were for the first time petrographically discriminated and described in the Geological Survey's *Annual Report* for 1896, these peculiar rocks had already been alluded to by the late A. CHAMPERNOWNE and described on his MS. map of Brent as "porcellanized rocks." Since 1893, the occurrence of rocks of this nature near Brent, Wrangaton (Kingsbridge Road), Ivybridge, and Cornwood has been a source of perplexity, owing to the apparent intercalation of inconstant bands among Upper Devonian Slates in a railway-cutting south of Brent (*Annual Report* for 1895, p. 7), and to the occurrence of a similar collocation in the upper part of a slate-quarry 2¼ miles east of Tavistock. These appearances might be explained by contortion, but if, as there seems now to be little reason to doubt, the Peak Hill rocks are altered representatives of the volcanic series and basement Culm-measures of Tavistock, the local association of bands of volcanic rock with fine calcareous matter in the uppermost part of the Upper Devonian Slates need cause no surprise. It is confidently anticipated that the detailed investigation of the rocks of the Tavistock area in the field will yield interesting results and enable the petrographer to identify the original volcanic or sedimentary materials of every variety of the Peak Hill series which is so well displayed around the greenstones of Cox Tor.

The advance of the revision of Cornwall has unfortunately been retarded by the continued ill-health of MR. J. B. HILL.

This officer was able during and after his convalescence to map some of the ground left by him incomplete in Argyllshire when he was transferred to England, and which it was desirable that he should put in order for his successor there. He was thus prevented from resuming active field-work from Falmouth as his centre until the end of August. But as he had the advantage of admirable cliff-sections in his immediate neighbourhood, he was able before the end of the year to make considerable progress in the study of the complicated structure of that region. Cornwall. (Mr. J. B. Hill.)

Mr. Hill has now mapped in detail the coast-line from Gerrans Bay to the Helford River, a strip little more than ten miles in length, but broken up by so many creeks that the comparatively small area has allowed of the mapping of over thirty miles of coast-sections. From that coast-strip as a base line the work has been pushed into the interior as far as the short available working season would permit.

On reference to the old geological map it will be seen that the area in question commences at the divisional line intended to separate Devonian from Silurian formations. The coast-section of the area coloured Silurian along the northern shores of Gerrans Bay has also been examined, and it may be stated briefly here that no stratigraphical break exists there, but that the strata coloured Devonian can be traced uninterruptedly into those coloured Silurian.

The section between Gerrans Bay and the Zoze Point consists of a series of blue slates with numerous alternations of harder beds containing a variable quantity of sandy material, and showing every gradation from a sandy slate to a strong grit. These strata extend eastward into the area which has been coloured Silurian. The appearance of limestones at Gidley Well and the fossiliferous quartzite at Carne serve to indicate the apparent incoming of another division of the stratigraphical series, though there is no evidence for drawing here a sharp divisional line to mark off two distinct geological formations.

For convenience of reference the strata on the north side of Gerrans Bay which have been coloured Silurian will be referred to in the following pages as the "Veryan beds," and the slates immediately to the west of them which have been coloured as Devonian will be cited as the "Portscatho slates." Besides these two divisions, two other series will be mentioned, one of which De la Beche described as the variegated slates; the other will be referred to as the Mylor series. The divisions succeed one another from east to west in the following order:—

1. Veryan Beds.
2. Portscatho Slates.
3. Variegated Slates.
4. Mylor Series.

(1) The Veryan Beds, consisting of blue slates mixed with thin limestones and a well-marked quartzite, strike into Gerrans Bay, and have not again been met with in the area now to be

described. Beds similar in character, however, make their appearance on the coast south of the Helford River, near the Nare Point. These beds are probably the south-western extension of the Veryan Beds, and they appear to occupy the same relative position to the Portscatho Series as the Veryan Beds do at Gerrans Bay; but any further account of this part of the series will be reserved until after a more detailed examination of the Veryan Beds and their correlation with the strata south of the Helford River, which will be undertaken next season.

(2) The Portscatho Slates succeed the Veryan Beds to the westward, and can be traced along the coast-line southwards to the St. Anthony peninsula, and their south-westerly prolongation is met with again on the coast of Falmouth Bay opposite. They consist of blue slates with a variable admixture of sandy and fine gritty bands.

(3) The Variegated Slates which bound the Portscatho series on the westward are well seen at St. Mawes, but still better in the excellent section between Pendennis Castle and Swanpool. The prevailing blue colour of the Portscatho beds has disappeared and is replaced by tints that vary from green to grey and buff, though blue argillaceous bands are still to be seen among them. The strata consist of alternations of argillaceous and fine sandy material, the colour varying with the character of the sediment; hence the general variegated appearance of the series. The weathering is equally characteristic; the beds become extremely friable, especially those of a sandy nature, and weather into a deep buff colour. On the whole the material is finer than in the Portscatho series, the coarser grit-beds of that series being here entirely absent. Within the Variegated Slates a narrow zone of sharply contrasted purple and green slates has been observed at St. Mawes and in the large dry dock at Falmouth. This zone is only a few yards in breadth, and has not been noticed save at these localities. It has been found of value, however, as an aid in correlating the variegated slates of Falmouth with those of St. Mawes which are separated by the Carrick Roads, a sheet of water more than a mile broad. The Variegated Slates of St. Mawes contain less of the buff sandy material than the Falmouth section, and are only marked off from the Portscatho series into which they gradually merge by a prevailing pale greenish hue.

(4) The Mylor Series, the most westerly of the four divisions into which the slates of this part of Cornwall have been provisionally divided, appears on the south-west side of the Variegated beds, and has been traced in the Falmouth area right up to the boundary of the granite. It is very well seen in the coast sections of Penryn Creek between North Parade and Boyer's Cellars; also in Mylor and Restronguet Creeks. Its westerly limit outside the granite area has not yet been ascertained. It consists of dark blue and black argillaceous and fine quartzose beds. These strata often have a fine striped or ribbon-like appearance, due to the very fine alternations of tiny seams of varying material. These thin laminæ are either alternations of siliceous and argillaceous material, or in some cases the differently

coloured laminæ are all argillaceous, but paler and darker in colour, those with most siliceous material weathering paler than the more purely argillaceous seams. Their most characteristic feature, however, is the presence of fragments clearly derived from the mass itself, which forms the matrix that encloses them. These fragments sometimes attain a length of five or six inches, and they graduate downwards to the size of small pebbles. As a rule they show little sign of attrition, the larger fragments being usually quite angular; the smaller are sub-angular, but sometimes even perfectly rounded. They consist both of argillaceous and of siliceous material; the latter, however, is most common, as it has offered greater resistance to the processes of disintegration. The large number of argillaceous fragments and the general absence of rounding may be taken as indicating that these materials have been transported but a short distance. The detritus is not uniformly distributed over the series, in many places it is rare or may even be absent altogether; and in such cases it is often difficult to be certain that particular beds belong to this series; but careful search will usually reveal some other characteristic, such as the presence of zones with the very fine rapid alternations of siliceous and argillaceous material. On account of the uneven character of the material in this series the slaty cleavage is not so perfect as in the other divisions. Cornwall. (Mr. J. B. Hill.)

Occasional instances of pebbles derived from the contemporaneously formed slates may be observed in the Variegated and Portscatho series; and at Rosemullion a bed occurs two or three feet in thickness, which is practically a boulder-bed not unlike those in the Dalradian series of Argyllshire and Perthshire. The pebbles are well rounded and vary in size, some attaining a length of three inches. They are made up of a hard sandy material, precisely similar both in colour and composition to the matrix in which they are embedded. This character being common to all the divisions is another evidence for linking them together in one continuous series forming part of one of the great geological formations.

It was pointed out in the account of the Cornish rocks given in the *Summary of Progress* for 1897 (which dealt almost entirely with the Portscatho series) that the slates everywhere showed evidence of intense foldings and puckerings, accompanied by innumerable minor faults. Similar evidence was met with last year in all the members of the group. Not only do the sections of each series afford ample instances of such plication, but the application of zonal mapping to the slates has brought out the fact that the large stratigraphical divisions are themselves interfolded with one another. In this way the Portscatho Slates and the Variegated Slates have been repeated in Falmouth Bay by folding. The Variegated Slates which succeed the Portscatho series uninterruptedly at St. Mawes, after being lost beneath Falmouth harbour, make their appearance again on the Pendennis peninsula, succeeding the Portscatho slates near Pendennis Castle. The junction of the two series can be followed to the south-west, and is seen on the coast midway between Pennance Point and Swanpool beach,

where the variegated series stretches into the interior; while the Portscatho Beds lying to the east of them can be traced along the coast as far as Maenporth. There, however, the Variegated beds come on again on the east side of the Portscatho Slates, and after an outcrop a quarter of a mile in width make way once more for the Portscatho Beds, which are continued along the entire section to the Helford River. A thin well-marked band of the Variegated series has also been brought up again near Pennance Point, but at no very great distance from the boundary of the main band. From their agreement in strike and their inclusion of the band of purple and green slates already alluded to, there can be little doubt of the identity of the Variegated Slates at St. Mawes with those of Pendennis. The coast-sections between the Veryan Beds at Gerrans Bay and the Variegated Slates at St. Mawes are so continuous that it may be confidently believed that the Variegated Slates at Pennance Point and Maenporth, which are situated on a geological horizon east of the Variegated Slates at St. Mawes, are not represented in the section between St. Mawes and Gerrans Bay, but that these bands have "nosed out" by folding before reaching the St. Anthony peninsula, at which they strike. The Maenporth Variegated and Portscatho Slates are the repetition by folding of the main bands that pass through Falmouth.

Minor folds and faults may be detected in a careful study of the coast-sections of any of the groups, although the inclination of both limbs of each fold being generally in the same direction, the plication is not so conspicuous as in a region of well-marked anticlines and synclines. Probably for this reason, the enormous amount of folding in the Cornish slates has not hitherto apparently been suspected, and thus erroneous impressions have been formed as to the thickness of the strata. Sections without evidence of folding are rarely continuous for any distance, and as far as observation has gone there appears to be as much folding in one series as in another. Perhaps the coast between Falmouth and Swanpool offers one of the most conspicuous illustrations of folding and minor faults. Alternation in material of the sandy and argillaceous beds of the variegated series has there produced irregularity in the folds, according to varying capacity of resistance to pressure, which the variegations in colour admirably bring out. Foldings, crumplings, faults, and strain-slips are so intermingled among these strata that the detailed structure is too intricate to be unravelled on a map.

The minor folds and puckerings are well brought out in the Mylor Series, where the fine alternations of siliceous and argillaceous material, together with the inclusion of fragments, have offered a less uniform resistance to pressure than the ordinary slates have done. Hence has arisen a set of strains and structures more complicated than where the slates are uniform in character. Moreover, the rock is often full of small thrust-planes, with a tendency to a secondary cleavage, while little movement-planes appear in the core itself, as in the Highland schists, with accompanying strain-slip cleavage. The cleavage-planes pass through

the axes of the minute folds, which often culminate in small thrust-planes The strain-slip cleavage is often as prominent as the dominant cleavage of the beds. Cornwall (Mr. J. B Hill.)

Quartz-veins are abundant over the entire succession of groups of strata, but they are most abundant in the Portscatho Slates, and least so in the Mylor Series. They show a tendency to diminish in number to the westward. Most of them share in the foldings and crumplings, and many of them are full of transverse cracks. They appear to be most numerous where faulting is most prevalent. They have furnished the greater part of the material for the various shingle-beaches that occur along the coast, as well as those of the older raised beaches of the district.

The beds over the whole area surveyed have a more or less uniform dip to S.E., but in a district so folded it is hardly safe to consider the observed dips as more than inclinations of the limbs of folds. The cleavage is usually slightly oblique to the strike, and the beds are rarely so uniform in character that the bedding cannot also be ascertained. The cleavage and folding appear to have been the result of movements proceeding from a direction between E. and S.E.

The district is singularly devoid of organic remains. Except in the Veryan Beds no fossils have been discovered, with the solitary exception amongst the Mylor slates at Penryn River, where, out of numerous specimens sliced for examination under the microscope by Mr. F. J. STEPHENS, a few slides were reported to have contained Radiolaria. The Veryan Beds are noted for the discovery by the late MR. C. W. PEACH of what have been regarded as Lower Silurian fossils in the quartzite bed at Carne. These fossils consist mainly of small specimens of *Orthis*. Many of the limestones from the same locality have been sliced for microscopic examination by MR. HOWARD FOX, and although found to contain encrinital and other remains, these have proved to be of too fragmental a nature to afford definite palæontological evidence of their geological age. MR. FOX has also found and described Radiolaria in certain cherts, and crinoidal remains in some thin black shales in the Veryan Beds. Although the rocks described in the foregoing pages are unfossiliferous except in one division, they have been divided, as already stated, into two geological formations; the Veryan Beds, which contain fossils, being included amongst the Lower Silurian, while the remaining three series, in which no organic remains have been found, are included in the Devonian formations.

If the apparent dip could be taken to be of value in determining the geological position of the strata, the Veryan Beds would be the highest and therefore youngest of the series, the Mylor group being the lowest and oldest. If this could be assumed to be their correct position, the various groups of strata to the west of the Veryan group would have to be considered as Lower Silurian, or even older. It is hoped that further light on the stratigraphical relations of the Cornish slates will be obtained as the revision of the county advances.

The large mass of granite which extends from Penryn to near Helston has its eastern boundary in the area that was mapped last season. In the small portion that has been examined the junction of the eruptive rock with the slates has been found to be concealed. The granite is usually grey in colour, and fairly coarse in texture, consisting of orthoclase and plagioclase, abundant quartz, and both white and black mica, with tourmaline usually present in small quantities. The felspar is sometimes porphyritic. No elvans have been observed in the granite so far as it has been examined, but a few have been mapped outside the granite area. Although the junction of the granite and slates has not yet been seen, the bulk of the slates that lie between Falmouth and the margin of the granite show no evidence of metamorphism. The slates, however, between Flushing and Penryn, as seen on both sides of Penryn Creek, are spotted, and at times crowded with ovate bodies; the particular mineral which composes these has not yet been determined. When fresh they are very hard and dark in colour, due no doubt to impurities taken from the slate. They often weather green and red, and are then quite soft. This character is the dominant type at the Flushing end of the section. The ovate bodies are fresher and larger in the neighbourhood of Penryn as they approach the granite.

Besides the granite and quartz-porphyries, other igneous rocks occur in the district which are evidently of greater antiquity. In most cases they have been considerably metamorphosed, and are much decomposed. They have been intruded as sills, and have shared in some of the movements and alterations which have affected the surrounding slates. Of these intrusive rocks, the principal is the mass that passes in a north-easterly direction through the northern part of Falmouth, and joins the south end of Flushing, where it widens to about 200 yards and then disappears. Although fresher specimens can be obtained from this sill than from others of the same class, it is generally much altered and in parts sheared. It is finely crystalline, and its main constituents (which, however, have not yet been precisely determined) appear to be green mica and decomposing felspar, with numerous carbonates and other decomposition products. A little further to the westward two other sills, separated only by a few yards of slate, are still more highly sheared and too decomposed for their mineral character to be definitely recognised. Moreover they are interfolded with slates, which adds to the complexity of their structure. In the old map only one sill has been coloured, and not improbably the separate outcrops belong to a single sill repeated by folding. The extension of the same rock separated by slate can also be seen on the Falmouth shore. Still another sheet of similar character occurs at Boyer's Cellars, further up the creek, and one also near Trevissome in the parish of Mylor. The slates sometimes included in them might lead to the supposition that these igneous bands are tuffs, but when the amount of plication in the district is considered there does not seem to be any reason against including them with the sills in

the neighbourhood, to which they bear a relation, and the intrusive character of which is beyond question. A comparatively unaltered sill of mica-trap, seen on the coast at Mawnan, is about four feet wide, massive, and comparatively fresh. It contains inclusions of quartz and crystalline felspathic rock, some of them being well rounded; also occasional pieces of slate. Some of these fragments attain a size of two or three inches. The rock is mainly composed of fine crystals of biotite and felspar, and appears to be earlier than the various faults which traverse the slates. It bears a strong resemblance to some of the lamprophyres which have been intruded into the schists of the Scottish Highlands. Cornwall. (Mr. J. B. Hill.)

CARBONIFEROUS.

The present field-work of the Geological Survey in the areas occupied by the Carboniferous system throughout the United Kingdom consists almost entirely in the revision of the various coal-fields on the scale of six inches to the mile. In the following summary of the progress made last year the several areas will be taken in order from south to north.

Devonshire Culm-measures.

The most southerly district of Carboniferous rocks on which the Survey was engaged lies along the western margin of Devonshire, where MR. USSHER surveyed the Culm around Tavistock. He found the strata there to consist of (1) hard, dark, shaly, and often cherty materials, which, associated with the volcanic series already alluded to in the section on the Devonian system, form the basement portion of the Culm; (2) dark shales, sandy, lead-coloured micaceous shales and grits, composed of quartz, felspar, and mica, with a black opaque matrix. The sandstones and grits seem to be local, and irregularly intercalated in the shales. Highly altered rocks, apparently belonging to the second group, are to be seen near the granite on the north margin of Cox Tor Moor. (Mr. Ussher)

The exact relations of the two groups (1) and (2) are nowhere manifest, owing to faults and the absence of junction-exposures. The arenaceous Culm-measures form a considerable tract between Beer Alston and Pillaton in Cornwall, already surveyed. In that area they rest on Upper Devonian strata, while the basement Culm chert-beds occur locally in inexplicable relation to them, and also rest on Upper Devonian rocks. During the past year two places, viz., Efford, east of Plymouth, and Wearde, south of Saltash, were revisited. In both, grits or sandstones occur, which from their constituents may be called arkoses. At Wearde these rocks seem to lie directly on volcanic materials in which a marked intercalation of chert-beds was detected in one spot. MR. USSHER, from the absence of traces of plants or other

Mr. Ussher.) organisms, was long in doubt whether to regard these rocks as a local rearrangement of siliceous tuff in the Upper Devonian series, or as Culm grits. Further study of the Culm districts now inclines him to regard them as Culm grits, and to consider the Wearde volcanic rocks as the equivalents of the Tavistock volcanic series. The only explanation which he can suggest of the occurrence of the Culm grit series, as it has been found, is that owing to irregularities of local vulcanicity during or preceding elevations of the sea-bed, the shales and grits were deposited unconformably upon basement Culm rocks or volcanic rocks, and in their absence directly upon the Upper Devonian strata. He would regard the Culm shales and grits as the base of the Middle Culm-measures, on the same general platform with the Ugbrooke Park conglomeratic beds, but he has found no proof of any break between the Middle and Basement Culm-measures of North Devon. The expression of a more definite opinion as to the relations of the Culm rocks must be postponed until the coast-section from Boscastle toward Bude has been studied in detail.

Volcanic group in the Carboniferous Limestone of North Somerset.

The Director General and Mr. Strahan.) The existence of certain igneous rocks in the Carboniferous Limestone series of Somerset has long been known. They are represented on the published Geological Survey Maps as intrusive in origin, and they have been described as dykes. Their true nature, however, was detected as far back as 1880 by PROFESSOR SOLLAS, who recognised the rocks as volcanic tuffs and amygdaloidal lavas.* In the year 1896 the ground was examined by MR. STRAHAN in connection with the revision of the South Wales coal-field, as a portion of North Somerset is included in one of the one-inch maps of that region. From his field-notes and the specimens he collected, it was quite certain that the Carboniferous Limestone on the south side of the Bristol Channel contains records of contemporaneous volcanic activity, and reference to the subject was made in the *Annual Report* of the Geological Survey for 1896 (pp. 61, 62), but further description of the evidence was reserved until the ground could be more carefully studied.

Accordingly, in the autumn of last year the various sections where these interesting rocks are exposed were visited by the DIRECTOR GENERAL and MR. STRAHAN, whose observations may here be briefly stated inasmuch as the evidence for the contemporaneous character of the igneous intercalations has never been

* *Proc. Geol. Assoc.* vol. vi. (1880), p. 378. In the "Handbook" prepared for the meeting of the British Association in 1898 at Bristol, Prof. Lloyd Morgan has recently expressed the same opinion regarding the nature of these rocks. (*Handbook*, p. 19.)

published. The occurrence of igneous bands in the Culm measures of Devonshire has long been recognised, but these rocks have shared in the general crushing and cleavage of the whole of that region, so that their original characters are often obscured, and even their stratigraphical position is not always clear. In the Somerset district, on the contrary, the evidence is precisely similar to that of the Derbyshire toadstone region, and brings clearly before the eye successive outflows of vesicular lava, and showers of volcanic detritus over the floor of the sea in which the Carboniferous Limestone was deposited. (The Direct General an Mr. Strahan

The district in which the volcanic rocks in question rise to the surface extends along the eastern shore of the Bristol Channel, from the limestone ridge of Middle Hope southwards for five miles to Uphill, where the western spurs of the Mendip Hills sink under the great alluvial plain. Its inland limits are uncertain, but volcanic rocks of the same age and type appear among the limestones of Wrington Warren ten miles to the east, while still further inland, certain eruptive masses have pierced the ridge of Old Red Sandstone to the north of Shepton Mallet. The actual area of sea-bottom over which volcanic eruptions took place probably far exceeded 50 square miles. There is no evidence of any central vent. On the contrary, the explosions appear to have taken place from small scattered orifices, as in other parts of the Carboniferous Limestone areas of Britain. We can recognise the probable neighbourhood of several of those active vents. One of them lay in the district of Uphill, the position of another or of more than one lay to the west of Weston-super-Mare, and to the north-west or west of the ridge of Middle Hope, while a more distant centre of eruption was situated not far from Wrington Warren.

It will be enough to give here some of the details of the more important sections. At Spring Cove, immediately to the west of the town of Weston, a cliff between the high road and the sea exposes the succession of rocks given in the subjoined table in descending order:—

Massive limestone full of fossils. The lowest three feet of the rock are crowded with fine volcanic dust, which under the microscope is seen to consist of fine vesicular lapilli.

Highly amygdaloidal altered basalt, having a "pillow"-structure, and with abundant calcareous and hæmatitic veins, and threads of carbonate of copper; about 35 or 40 feet.

Red limestone, full of fine volcanic dust, and passing down into the ordinary grey fossiliferous limestone.

This section places clearly before the mind the succession of volcanic events of which it retains the record. From some vent in the neighbourhood fine dust continued to be ejected during a considerable interval, for the limestone, through some 30 or 40 feet of its mass below the basalt, is full of disseminated volcanic particles. It may be remarked in passing that nowhere in the British Isles can more typical examples be found of the chief characteristics of the Carboniferous volcanic tuffs than in the volcanic tract of North Somerset. The lapilli abound in finely

The Director General and Mr. Strahan.)

vesicular basic pumice, and show the prevalent dull-green palagonitic modification of what was no doubt originally a basic glass.

At last a stream of lava flowed over this part of the sea-bottom. It rested immediately on the calcareous sediment to which it is now firmly bound, and which is highly crystalline; but there is no conclusive evidence that this crystalline structure has been due to the heat of the overlying lava. This lava is now much oxidised and decayed, strongly amygdaloidal, and presenting the characteristic "pillow" or sack-like structure that has been so frequently observed among the submarine volcanic eruptions of former geological periods. The interstices between the large irregularly shaped pillow-like masses of the sheet have been filled up with calcareous material, which, in the form of a network of limestone ribs with veinings of hæmatite, traverses the rock. The basalt contains also lumps of limestone, while some of its more solid parts have been broken up and have been involved in portions possessing a much more slaggy structure. The bottom of the sheet is much brecciated, the fragments being finely vesicular. The lava has been sliced and examined under the microscope by MR. TEALL, who reports regarding it as follows:—

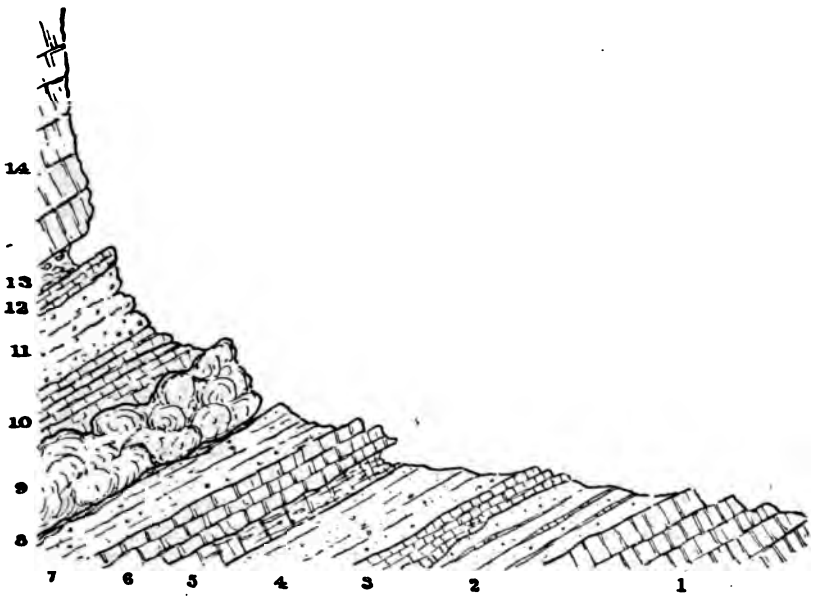
"The lava from Spring Cove, Weston-super-Mare [E. 3212 (23)], is a fine-grained, chocolate-coloured rock, composed of pseudomorphs after olivine, and probably augite, in a groundmass showing microlitic structure. The phenocrysts are represented by pseudomorphs in carbonate. The microlitic felspars of the groundmass are colourless, but they no longer show their characteristic optical properties. The groundmass is deeply stained with ferric oxide. Although all the minerals have been destroyed, the structure has been perfectly preserved, and there can be no doubt whatever that the original rock was an olivine-basalt."

On the rugged upper surface of this basalt the limestones have been laid down in the same way as underneath. The volcanic episode, although it locally interrupted the continuity of the accumulation of organic detritus on the sea-bottom, seems to have effected no change in the general conditions of sedimentation. Fine volcanic dust appears in the overlying limestone for about three feet above the surface of the lava, and thereafter the calcareous rock assumes its usual highly fossiliferous character.

That the little vent from which the discharges took place lay to the westward, under what is now the Bristol Channel, may be inferred from the disappearance of the volcanic zone as the ground is traversed in the opposite direction. Fragments of the amygdaloid were found by Mr. SPENCER PERCEVAL at the Toll-gate, which show that this rock extends inland for a mile and a half. But immediately to the east over the bare limestone surface above Kewstoke or Milton Hill and the ground towards Worle MR. STRAHAN could find no trace of it.

Two miles to the north of Weston another parallel ridge of limestone, known as the Middle Hope, runs out into the Bristol Channel and displays along its northern coast-line a still more interesting intercalation of contemporaneous volcanic material. Three separate sections have been laid open by the sea within

the space of a mile The most westerly of these is illustrated in the accompanying figure, which represents the whole volcanic group, about 100 feet thick, intercalated between the ordinary crinoidal limestones (1 and 14). At the base from low- (The Director General and Mr. Strahan.)



Section of Volcanic Rocks in Carboniferous Limestone.
Middle Hope, Mouth of Severn, Somerset.

water up the beach, between 30 and 40 feet of highly fossiliferous crinoidal limestone (1) appear from under the sea in successive beds, which towards the top pass into a reddish banded limestone with thin partings of red clay. The argillaceous material probably results from decayed volcanic dust, and marks the beginning of the eruptions from the vent in this neighbourhood, for above the reddish limestone lies a greenish tuff (2) with calcareous bands. Much of this band is concealed under the detritus of the beach, but it may be more than 12 feet thick. It is followed by a thin-bedded limestone (3) crowded with *Productus* and other fossils, about 3 feet thick, but swelling out to a much greater bulk further east. Next comes a group of green and red tuffs (4) with lenticular bands of limestone. Some of the tuffs are marked by bunches of coral in the position of growth. At the top of these tuffs a band of red ferruginous limestone (5) appears; it is thin-bedded, lenticular, and about 5 feet thick. It passes upward into about 15 feet of highly fossiliferous limestone (6). The quiet interval marked by the intercalation of this crowded mass of organic remains was brought to an end by a much more vigorous display of volcanic energy. The explosions began with the discharge of ashes, which in the section are now represented by from 12 to 14 feet of green tuff (7). The lapilli varied continually in size

(The Director General and Mr. Strahan.)

so that the tuff is made up of lenticular layers of fine and coarser material. The band, moreover, is much veined with calcite, no doubt derived from the solution of calcareous organisms either in the surrounding limestones or in the tuff itself. The top of this accumulation of pyroclastic material is marked by a thin red cherty layer (8), immediately above which lies the chief member of the volcanic group—a dull green amygdaloid of the usual basic character (9). This bed, perhaps 12 to 14 feet in thickness, has been a thoroughly vesicular scoriaceous basalt. It shows the "pillow" structure already referred to, some of the "pillows" being a yard or more in diameter. The vesicles, sometimes 4 inches long, have been filled with calcite. The upper surface of the sheet is rugged and scoriform, and the overlying sediments have filled up its hollows.

The outflow of this lava was followed by a much quieter phase of volcanic activity, when only occasional showers of dust were discharged over the floor of the sea on which the calcareous organisms had again spread. This portion of the record is contained in a band, about 9 feet thick, of lenticular seams of blue limestone (10), full of fossils, and divided by partings of fine tuff. A more prolonged and vigorous discharge of ashes is indicated by a band of green tuffs about 9 feet thick (11). The base of this band passes down into the ashy limestone group (10) below, so that there was obviously no interruption in the continuity of the volcanic phenomena. But the discharge of the ashes must have been sufficiently gentle or intermittent to allow of the continued presence of living organisms even on the bottom over which the volcanic detritus was accumulating, for the tuff contains lenticular seams and nodules of crinoidal limestone. In this band one of the characteristic features of Carboniferous tuffs already referred to is well displayed—the presence of abundant lapilli of a minutely vesicular basic pumice. A thin slice prepared from one of the calcareous bands was found under the microscope to be full of these lapilli and of various organisms, among which MR. NEWTON detected foraminifera (*Endothyra ?*), and probably also echinoderms, corals, and entomostraca.

The gradual cessation of volcanic activity was marked by a return of the phase of sedimentation that had preceded the last more violent outbreak. The tuff-band just described passes upward into a red limestone (12) about three feet thick, banded with lenticular seams of green tuff like that underneath. Then comes a reddish nodular limestone (13), about three feet thick, with irregular partings of a ferruginous argillaceous material which may be highly decomposed volcanic detritus of the finest kind, marking some of the last efforts of the expiring volcano. Immediately above lies the ordinary well-bedded coarsely-crinoidal limestone of the district. Its lower seams include little blotches which may possibly also be decayed ashy material. But above this part of the section all trace of volcanic activity disappears, and the normal limestone, made up entirely of organic remains, resumes its place.

The next section of the volcanic group has been laid bare in a small bay three-quarters of a mile further to the east. Here again the rocks have been thrown into a highly inclined position, so that a considerable thickness of strata has been packed into a narrow strip of the beach. Short as is the interval between this outcrop and that just described, the succession of strata between the two places has entirely changed. The sheet of lava has disappeared, and a number of the tuffs which towards the west are separated by layers of limestone here form more continuous deposits. But the whole volcanic group is thinner. (The Director General and Mr. Strahan.)

At the base of the section the thick crinoidal limestone, with bunches of coral in the position of growth, passes upwards as before into reddish banded limestone with red clay partings, which no doubt represent much-decayed fine volcanic dust, for immediately above comes a deposit about 50 feet thick of green finely-bedded tuff. This band repeats the characters above described. It includes in its upper part a coarser layer, which encloses pieces of limestone, chert, and basalt, sometimes six inches long. It is marked also by the same evidence of contemporary organic growth and deposit, for at different platforms throughout its mass occur thin layers of ashy limestone and dark chert, while some of the finer portions of the tuff are nearly as fossiliferous as the ordinary limestone, being crowded with crinoidal joints, corals, bryozoa, brachiopods, &c.

Above this tuff lies a bed of hard, fine-grained, finely-laminated purple and grey sandstone, about two feet and a half in thickness, the most marked feature in which is the presence of numerous small cylindrical pencil-like bodies which descend from the upper surface of the band vertically across the lamination of the sediment. They may be worm-burrows. This arenaceous band seems to mark a pause of some duration during which volcanic activity was quiescent, and the calcareous organisms had not yet recovered their former place over this part of the sea-floor. Possibly this band may be paralleled with the lenticular limestones (No. 10) in the previous section.

Eruptions were renewed for the last time, when a quantity of ashes was discharged, now represented by a band of green and red tuffs from five to seven feet thick. These materials may be continuous with the band No. 11 further west, like which their layers of coarser and finer material are mingled with much calcareous material. They are well banded, and in their upper part enclose rows of blocks of finely slaggy amygdaloid. Immediately above them comes a limestone 12 feet thick, which passes upward into some red, impure, decaying and probably ashy limestone, and this is followed by the great overlying mass of crinoidal limestone.

The most easterly of the three coast-sections lies 600 feet further along the shore. The upper part of the volcanic series is there cut out by a fault, which brings the tuff against the limestone. The calcareous bands in the tuff are here much thicker and more numerous than they are further west, and continue to

(The Director General and Mr. Strahan.)

be crowded with organic remains. The volcanic material appear to be dying out in an easterly direction. Taking the whole evidence of this series of sections, we may reasonably conclude that in this instance also the eruptive vent lay somewhere to the west or north-west of the present shore-line.

The inland tract where contemporaneous volcanic rocks have been found in the Carboniferous Limestone lies on the ridge rather more than a mile to the north-east of Wrington. The ground has not yet been mapped in detail, but a traverse of it in different directions shows that a more careful examination of its rocks will entirely confirm the results obtained from a study of the shore-sections. Two outcrops (which may really belong to the same band) were noticed in Goblin Combe, one of them about 1,500 feet south from Warren House, the other about half a mile further to the south-east. At the latter place a group of tuffs is seen emerging from underneath a sheet of limestone. These tuffs consist of alternations of fine and coarser green and red volcanic dust and lapilli, with partings of limestone. They abound in the usual finely vesicular basic pumice. They are generally calcareous, and pass laterally and vertically into ashy limestone. The limestone-bands in turn are full of volcanic sediment, especially of lapilli of the green pumice. Some of these are partially oolitic, the oolitic grains being scattered through the ashy material.

At the lower or western outcrop blocks of a decaying basic amygdaloid are scattered over the surface. This rock, evidently a lava like those already described, must no doubt be in place close at hand. By following the detritus in mole-hills it is possible to trace its probable line of outcrop for some distance along the south side of the Combe. At the same place numerous pieces of ashy limestone and calcareous tuff may be picked up. These rocks are obviously also in place hereabouts, though their outcrop seems to be at present concealed. They resemble the strata seen half a mile up the valley. They must lie under the thick mass of fossiliferous limestone in which Cleve Combe has been excavated, and they probably overlie the limestone seen in Goblin Combe just above the tract where the volcanic detritus appears at the surface. Though the available evidence is defective, it is sufficient to prove the approximate position of another volcanic vent in the inland part of the Carboniferous Limestone, and to indicate that from this vent not only tuff but a sheet of vesicular lava was discharged over the floor of the sea.

A group of masses of igneous rock is shown on the Geological Survey Map (Sheet 19), rising along the ridge of Old Red Sandstone to the north of Shepton Mallet. These masses were also visited by the DIRECTOR GENERAL and MR. STRAHAN, with the view of ascertaining whether they formed part of the volcanic series which has now been described. But they were found to belong to a different petrographical series. Thin slices prepared from the freshest of the rocks in Moon's Hill quarry and from Beacon Hill have been examined by MR. TEALL, who finds that

they are undoubted andesites.* They appear to rise intrusively through the (Upper) Old Red Sandstone. They have none of the characters of true lavas, nor do they seem to have any accompaniment of tuff or agglomerate. Their age must remain undecided. They are persumably younger than the Old Red Sandstone, which in their immediate neighbourhood passes conformably upward into the shales and limestones at the base of the Carboniferous system. They may possibly belong to the Carboniferous volcanic series. Their more acid character than that of the lavas of Weston, Middle Hope, and Goblin Combe would not be a valid objection to such a relationship, for the intrusive sheets and bosses of the Carboniferous series in the south of Scotland and in Ireland are often much less basic than the contemporaneous lavas. This question, however, must remain until the district is surveyed in more detail. (The Director General and Mr. Strahan.

South Wales Coal-field.

The re-survey of the Coal-field of South Wales and surrounding tracts has made steady progress during the past year, though the area surveyed would have been larger had it been practicable to retain MR. GIBSON in the district instead of temporarily transferring him to North Staffordshire. In the examination of the northern part of the area MR. CANTRILL continued his mapping of the Old Red Sandstone and Lower Carboniferous formations, while MR. STRAHAN and, for a short time in the autumn, MR. GIBSON carried on the survey of the Coal-measures. MR. TIDDEMAN, who was joined in the latter part of the year by MR. CANTRILL, was engaged upon the southern part of the coal-field and on the Secondary rocks which border it.

The following summary of the recent progress of the Coal-field work has been drawn up by MR. STRAHAN. It embraces the results arrived at by his colleagues and himself.

Carboniferous Limestone.—In carrying on the mapping of the Carboniferous Limestone westward in Brecknock, MR. CANTRILL finds that the Lower Limestone Shales keep their general character, but that the limestone at their base tends to dwindle away or to give place to shale. In Nant Byfre it is represented by a band of limestone eight feet thick which occurs sixteen feet above the base of the shales; westward of this stream no such rock has been recognised. (Mr. Cantrill

---

* MR. Teall's remarks on these rocks are as follows :—

E. 3195 (11), Beacon Hill.

Conspicuous phenocrysts of plagioclase and pseudomorphs, often a ferromagnesian constituent (augite or enstatite) in a felsitic matrix containing traces of felspar-microlites. The rock is too much altered for precise determination, but it undoubtedly belongs to the andesites.

E. 3197 (13), Moon's Hill Quarry.

A dark-coloured andesite composed of phenocrysts of plagioclase, augite and green serpentinous pseudomorphs after enstatite (?) in a microlitic groundmass.

(Mr. Cantrill) The main mass of the limestone, above this lower shaly subdivision, consists broadly of a lower division of dark limestone, in part oolitic; a middle mass of light-grey oolitic limestone; and an upper zone of dark limestones with abundant chert-nodules. A band (about three or four feet thick) rich in coral has been traced across the moorlands on either side of Glyn Tawe, at a height of 20 to 40 feet above the base of the main limestone. There are also bands of sandstone or grit with white quartz-pebbles in the main limestone, as on Pant Mawr and westward of Glyn Tawe, though their presence is seldom indicated by more than loose blocks. At the base of the light oolite there occurs a sandstone or sandy limestone, which weathers into an incoherent yellow sandstone. This band is 10 feet thick near the River Giedd, and is just reached in the bottoms of some of the quarries on Cribarth. Another grit-band 2 feet 6 inches thick is exposed in a quarry at Penwyllt at the top of the light oolite.

The upper limit of the dark cherty subdivision includes a thin limestone highly charged with quartz-grains and threads of sand. Above this band and immediately below the basal conglomerate of the Millstone Grit, some black shales with two or more thin bands of nearly black argillaceous limestones make their appearance at Careg Cadno and persist westward. The limestones are decalcified to a depth of from six to ten feet along the outcrop, and are dug out to that depth as "rottenstone" in a series of excavations which extends almost continuously from Penwyllt as far westward as the mapping has extended.

(Messrs. Tiddeman and Cantrill.) The tracing of the Carboniferous Limestone in the Vale of Glamorgan, on the south side of the coal-field, has been continued by MESSRS. TIDDEMAN and CANTRILL. MR. TIDDEMAN finds that the central axis of the great Cardiff anticline ranges from Penllin, by Crackhill, passing thence two-thirds of a mile south of Ewenny Priory, and just north of Ogmore Castle. It next traverses the Merthyr Mawr Burrows, and passes due westward out to sea at Porthcawl. So much however is the limestone masked by patches of later rocks, that this line is by no means apparent without a careful study of the dips. Thus on the north side of the anticline the actual top of the formation can be fixed in one place only, viz., in the railway and tramway opposite Angeltown Asylum, while on the south side its underground extent beneath the newer rocks is unknown, except for some three or four inliers. Of these inliers, none of which had been previously detected, one is described by MR. TIDDEMAN as consisting of a narrow strip of limestone one mile long, brought up between two faults. It is well seen in the Vale of Glamorgan Railway, and is here and there covered with patches of conglomerate which are apparently of Liassic age, but are not easily distinguished from the Carboniferous Limestone. Another example occurs as a large inlier of erosion in the south-east end of Clemenston Park, where, as the limestone dips north, there may be reason to suspect the existence of another anticline south of the large one mentioned. A third inlier is exposed in a small quarry, also with a northerly dip,

half a mile W.N.W. of Wick. A fourth, which, however, is only doubtfully referred to a Carboniferous age, lies half a mile north of the last, and consists of tufaceous limestone with traces of conglomerate. (Messrs. Tiddeman and Cantrill.

The Carboniferous Limestone of the Vale of Glamorgan is usually well-bedded, and grey to black in tint, varying to light-grey and drab-brown. White shelly limestone, such as is common in the north of England, is seldom seen, but fossils abound, especially in the lower beds, as at Penllin. Corals and large *Producti* occur in fine preservation, dotted over the bedding planes near Southerndown and Porthcawl. Oolitic structure is common, and occurs both high up and low down in the formation. The oolitic rock shown in the road between Southerndown and St. Brides Major is high up, while that exposed between Merthyr Mawr and Candleston occupies a much lower horizon. Another oolitic band of considerable thickness crosses Newton Downs, high in the limestone, but not at its top. A singularly cavernous bed, to a great extent filled up with chalcedonic silica, but containing also small crinoid joints, occurs near the base of the limestone at Penllin. Cherts are not uncommon, but are perhaps most abundant at the Witches' Point, Southerndown.

The Lower Limestone Shales have been recognised by Mr. Tiddeman at the centre of the anticline east of Penllin. They consist of shales with interbedded limestones dipping southwards beneath a scarp of the main limestone. Towards the north they are probably faulted, but westward yellowish and greenish shales and clays with decalcified crinoidal limestones or "rottenstones" are exposed for some distance. These strata have hitherto been mistaken for Rhætic shales.

MR. CANTRILL in examining the range of these rocks further east found that the bold east and west escarpment of limestone and shales of Bonvilston curves to the north-west and disappears near Welsh St. Donats under a plateau of what appears to be Lias concealed by Glacial Drift. It reappears around part of Stalling Down, where a thick band of purple oolite occurs at the base of the shales. At Llansannwr the shales contain several oolitic bands, the lowest of which is at least 25 feet thick.

Some lead-veins were formerly worked at St. Hilary in the main limestone, and a lode which is thought by MR. TIDDEMAN to form the northern boundary fault of the Lower Limestone Shales at Penllin has been tried for lead at Llangan.

Millstone Grit.—The lower part of this subdivision, composed of coarse quartz-grits loaded with pebbles of vein-quartz and irregularly split up by thin partings of dark shale, forms the barren moorland of Pant Mawr and the heights of Careg-gôch, Dysgwylfa and Careg-lem—large areas on which are entirely devoid of vegetation. It furnishes the purely siliceous sand from which the celebrated Dinas Fire Bricks are made, and is worked for that purpose at Penwyllt. Formerly these grits and some much crushed sandstones above them were worked on Cribarth also. (Messrs. Strahan and Cantrill.)

The shales which form the middle part of the Millstone Grit

(Messrs. Strahan and Cantrill.)

occupy a large part of the tract which separates the grit-scarps from the Coal Field, but are so thickly overspread with boulder-clay that no opportunities have occurred of investigating the fossiliferous limestones in them which have been described in previous *Annual Reports*.

The Farewell Rock, or uppermost sandstone of the series of sandstones and slates of which the higher portion of the Millstone Grit consists, presents no essential difference to the sandstones of the Coal Measures, and is not easily separable from them. The line, in fact, between these formations merely marks an arbitrary division useful for purposes of classification, but of no geological significance. The base of the Millstone Grit, on the other hand, indicates an abrupt change of original conditions of sedimentation over a large area, for not only were sand and pebbles spread abundantly over a region in which only limestone or fine sands had previously been accumulating, but a certain amount of erosion of the sediments already deposited took place. It is not impossible that the absence of the "rottenstone shales" east of Careg Cadno may be due in part to such erosion, but their persistence, when once they have appeared, makes it more probable that their present extension represents the limits up to which they originally reached.

This slight erosion of the top beds of the limestone is not to be confused with the subsequent dissolution of that rock which has sometimes proceeded on so great a scale, both in Monmouthshire and Glamorganshire, as to simulate an unconformity. Attention has been drawn in previous *Reports* to the lowering of masses of Millstone Grit by the removal of their limestone support, and in the district examined last year MR. CANTRILL finds that there are several small patches of Millstone Grit on the west of the Tawe lying as much as 100 feet below the level of the main grit escarpment. The bedding is but little disturbed, and the masses rest on the "rottenstone shales," showing that their position is not due to contemporaneous erosion of the top beds of limestone. They are thought by MR. CANTRILL to have moved slowly down and away from the parent bed after the fashion of à landslip.

(Messrs. Strahan and Gibson.)

Coal-measures.—The equivalents of the Steam Coals of the Rhondda Valleys have now been traced by MR. STRAHAN and MR. GIBSON westward along the north crop as far as Ystradgynlais. They include in descending order the Red, the Stwrain, and the White Veins, which have been worked to a small extent here and there, and below these the Four Feet, the Eighteen Feet, the Nine Feet or Big, and the Brass or Yard Veins, all of which have been, or are being, extensively worked. The Eighteen Feet and Nine Feet Veins correspond to the Six Feet and Nine Feet of Aberdare, but in the ground last surveyed they have changed from the condition of steam-coals into that of true anthracitic coals, after passing through an intermediate stage in the Vale of Neath.

The base of the Coal-measures is not easily identified owing to the poor development of the Farewell Rock. The Cnapiog coal, however, which is the lowest seam in the Vale of Neath and at

Hirwain, can be recognised in the Vale of Swansea also, and the base-line has been drawn, as in those districts, so as to include this seam and some shales below it in the Coal-measures. A considerable thickness of barren measures which form the Mynydd y Drum separate the Stwrain from the Red Vein, but the Red Vein is followed at no great distance by the Welsh Vein, the Pinchin, the Ynysarwed, and the Pen-y-graig. Of these the Ynysarwed is regarded as the representative of No. 2 Rhondda, and the Pen-y-graig of No. 1 Rhondda, a view which is borne out by the fact that the Ynysarwed lies at the foot of a crag of grit and marks the oncoming of the great mass of Pennant sandstone. It is noticeable also that a band of conglomerate, containing lumps of ironstone and pebbles of quartz in a coarse grit matrix, lies a few feet above the coal, a feature which has frequently been observed in the roof of No. 2 Rhondda elsewhere. The Ynysarwed coal is about 2 feet 10 inches thick, and is being worked at Crynant and Resolven as a steam-coal. (Messrs. Strahan and Gibson.)

The measures above No. 2 Rhondda continue to show that change which has been referred to in former *Annual Reports* as taking place westward. Though chiefly composed of massive grits in the lower part, they contain many bands of shale with thin seams of coal in the upper part. The coals also tend to become more important westwards, and have been largely worked in the Neath and Swansea neighbourhoods. The re-survey of this tract having been only begun, it would be premature to attempt a precise correlation, but so far as the evidence yet collected goes the seams appear to correspond to the Llantwit group, the lowest of them being the Graigola, which becomes the Wenallt, the Bettws Four Feet of the Llynfi and Garw Valleys, and the Ty-du Vein of Llandyfodwg and Ton-yr-efail. The Ty-du Vein is probably the Pen-y-groes Vein, which lies about 60 yards below Llantwit No. 3 in the Llantwit basin. Whether any representative of the Mynyddislwyn Vein or Llantwit No. 1 exists at Neath or Swansea cannot yet be stated.

These measures lie in a deep syncline which runs east and west across the Vales of Neath and Swansea, and is traversed by a succession of large north and south faults. Though rising gently northwards to the north crop, they turn up abruptly towards the south, and the massive grits of the lower part of the Pennant emerge along the north side of Swansea Bay with inclinations of 40° and 50°, forming a conspicuous range of hills between Baglan and Swansea. At their base there occur three seams of coal, about ten yards apart, which have been worked on the east side of Briton Ferry under the names of the Tor-mynydd, Jonah, and White Veins. The Tor-mynydd Vein corresponds in position to the Ynysarwed of the north crop and to the Rock Fawr of the south crop, and therefore represents No. 2 Rhondda. This identification affords a clue to the position of the lower productive measures in the foreshore, where they have not yet been proved, but it should be remembered that the Moel Gilau Fault, where last seen near Baglan, ranges in a westerly direction across Swansea Bay, and that it is accompanied

Messrs. Strahan and Gibson.) by much disturbance of the strata, especially on its northern or upthrow side.

The disturbance alluded to takes the form of somewhat sharp folding, such as is seen in the sides of the Cwm Avan Valley. It may be noticed, however, that the plication is generally confined to such plastic strata as compose the infra-Pennant series, the massive Pennant grits themselves showing but little disturbance. A good example of the different effects produced by compression on the two rocks is furnished along the Vale of Neath Disturbance, where the Pennant escarpment exhibits a gentle and uniform dip, though the soft measures below it are thrown into sharp folds. Explorations are now showing that the lower measures are too much crushed and broken over considerable tracts near the head of the Rhondda Valleys for their coals to be workable, though the Pennant rock overlying them is unbroken, a fact which emphasises the importance of tracing out such lines of crush as those of the Vale of Neath and Cribarth in the greatest detail.

The anthracitisation of the coals which has been alluded to in former *Annual Reports* proceeds steadily in a direction somewhat west of north. The lower seams of the north crop in the Vale of Swansea are true anthracites, while the Ynysarwed Vein or No. 2 Rhondda becomes a steam-coal at Resolven, and is intermediate between a steam-coal and an anthracite at Crynant. Of the Neath veins the Wernfraith alone is a house-coal, all the others being steam-coals, though they correspond to the Llantwit group, the most noted house-coals of the coal-field. No connection has appeared between the anthracitisation and the faulting, but the change seems rather to be a form of regional metamorphism dependent upon the temperature to which any part of the coal-field has been subjected during depression, as was suggested many years ago by DE LA BECHE. More precise information than we at present possess as to the changes undergone by any one seam, and as to the direction of maximum change, is highly desirable.

A few fossiliferous horizons have been noted in the Coal-measures. The shales above No. 1 Rhondda in Resolven Mountain have been found by MR. GIBSON to contain slightly calcareous ironstone nodules, in which entomostraca of the genus *Carbonia* are associated with *Anthracomya*. Black shales with entromostraca have been noted by him also beneath a coal that may represent No. 3 Rhondda, 250 feet below the Ynysarwed Vein or No. 2 Rhondda. MR. HOWEL, of Bryn Coch, has furnished specimens of *Leaia* and *Anthracomya*, with the remark that they abound in the shales associated with the Graigola seam near Neath.

Mr. Strahan.) *Faults and Disturbances.*—In the *Summary of Progress* for 1897 the course of the Vale of Neath Disturbance was traced, and mention was made of a parallel line of fold of which evidence had been obtained seven miles to the north-west. These two great lines of crush have now been more fully worked out, and their general similarity as well as parallelism have become

strikingly evident. Both may be described as narrow belts of (Mr. Strahan
contorted strata, the contortion occasionally passing into fracture and even overthrust, as at Dinas Rock. Though accompanied by some normal faulting, they are not comparable in any respect with the clean-cut normal N.N.W. faults which form so conspicuous a feature in the structure of the coal-field, but have evidently resulted from compression brought about by a force acting from the north-west. That they afforded relief is clear from the undisturbed condition of the strata on either side of and between them. (*See* Plate II.)

At its point of entry into the coal-field the Vale of Neath Disturbance consists of a series of sharp flexures, the net result of which is a downthrow to the north-west of about 200 yards, for at Glyn Neath the top of the Millstone Grit of the southern side of the valley would, if projected, pass that distance above the top on the northern side. Further west, however, as subsequently explained, the downthrow is in the opposite direction, for the Ynysarwed (No. 2 Rhondda) and other seams crop out about two miles further north on the south side than on the north side of the valley, an effect which would be brought about by a vertical downthrow to the south-east of about 250 yards. Here again, however, the displacement is probably due to a number of folds rather than to a clean fracture, but the disturbed belt coincides with and is everywhere hidden by the alluvial flat of the Neath. This is the last definite evidence obtained of the existence of the disturbance; it probably dies away a short distance to the south-west, for no trace of it exists at Briton Ferry.

The parallel line of disturbance alluded to may conveniently be named after Cribarth, a conspicuous anticlinal ridge of limestone flanked by Millstone Grit. The disturbance enters the area undergoing revision in Glyn Senni, and runs thence to the Tawe Valley through ground surveyed by MR. CANTRILL. It was found by him to traverse a depression between Fans Fraith and Gihirych as a faulted syncline, the effect of which was to repeat in Fan Gihirych the hard red sandstones which form Fan Fraith, at the same time that it introduced a small outlier of "grey grits" and limestone in the depression. It is, therefore, a downthrow to the north-west. The disturbance can be traced thence by high dips towards the Tawe Valley, which it enters to the north of Penwyllt. Here it consists of a strong anticline crossing under Craig-y-Nôs Castle and forming the crest of Cribarth, with an equally marked syncline on its north side, while a syncline in the Tawyneu Valley and an anticline in Cefn Cûl are also probably connected with it.

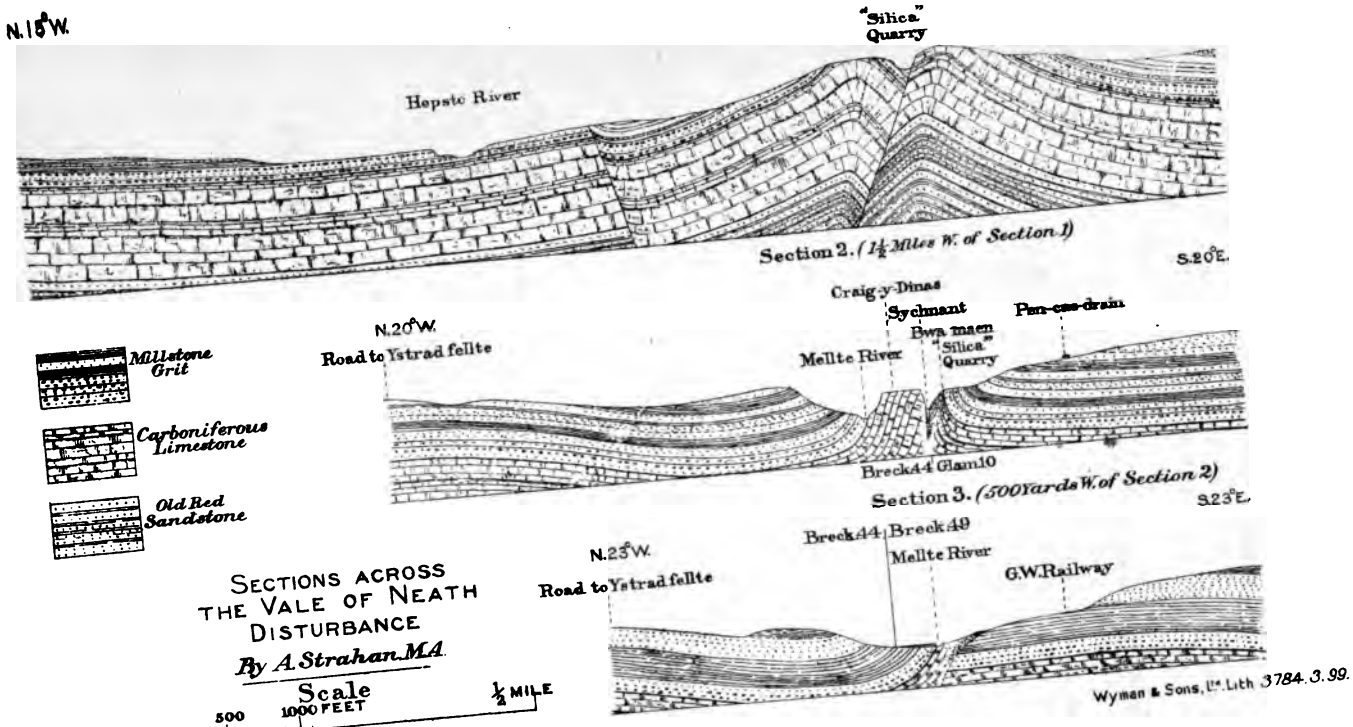
The crags and rocky sides of Cribarth afford a perfect dissection of the disturbed belt, and show that it consists there of a series of sharp synclines and anticlines. They enable us also to see that though the disturbance as a whole keeps its character for some miles, yet the individual folds composing it rarely run more than half a mile, the principal anticline of Cribarth alone excepted, which continues for not less than three miles. The

(Mr. Strahan.) anticlines and synclines therefore may be more correctly described as elongated domes and basins respectively, rapidly giving place to one another, and crowded into a belt of about a mile in width. The disturbance, as a whole, has at present been traced for a distance of about ten miles in a general direction W. 35° S.

The fact that these two great lines of disturbance run nearly at right angles to the north and south system of faulting, but in a direction not widely different to that of the pre-Triassic folding of South Glamorganshire, suggested that they also may belong to the earlier age, and this inference seemed confirmed by the fact that in one case at least the anticlinal axis was distinctly shifted by a north and south fault, as subsequently described. On the other hand, this year's work has made certain what was only suspected before, that some powerful faults of the north and south system run up to the Vale of Neath Disturbance and lose themselves in it. A notable example is that of the Pen Castell Fault, a large downthrow to the west, which has been traced by MR. GIBSON from the south into the disturbed belt near Resolven, but which does not emerge on the north. Still more significant is the behaviour of the Glyn Corrwg Fault, a great westerly downthrow, which runs into the disturbance from the south and turns at right angles to follow it westward. The proof of this structure lies in the fact that the Vale of Neath Disturbance is a downthrow to the north down to its intersection by the fault, but that at that intersection it suddenly becomes a downthrow in the opposite direction. It is evident therefore that the strata in the angle formed by the fault on the east and the disturbance on the north have dropped.

Another fact which may throw light on the age of the two disturbances is that both have obviously influenced the direction of the river-system. The Neath below the confluence of its five principal tributaries follows the one rigidly; the Tawe, though it crosses the other, turns immediately to run parallel with it. In this the Vale of Neath and Cribarth Disturbances differ both from the north and south system of faulting, and from the pre-Triassic east and west folding, neither of which has had any share in determining the directions of the rivers.

The three sections forming Plate II. have been drawn to illustrate the points mentioned above. Section 1 is taken through the great excavation on Penderyn Foel, where crushed Millstone Grit has been dug for the manufacture of fire-bricks. The highly inclined grits and the normal fault are fully exposed in the pit, as depicted in the section, while the faulted syncline shown further north is readily traced in and along the south side of the Hepste. Section 2, one and a half miles west of Section 1, shows that the fault has passed into a belt of broken limestone intersected by an infinite number of veins of calcspar, this crush-rock forming the bed of the Sychnant. The syncline to the north is still recognisable, while the main anticline has gained intensity, and admirably expresses the compression to which the whole structure is due. In the Bwa Maen, or Bowstone, the folding


N.15°W.
"Silica" Quarry
Hepste River
Section 2. (1½ Miles W. of Section 1)
S.20°E.
Craig-y-Dinas
Sychnant
Pen-cae-drain
N.20°W.
Road to Ystrad fellte
Bwa maen "Silica" Quarry
Mellte River
Millstone Grit
Carboniferous Limestone
Old Red Sandstone
Brecka44 Glam10
Section 3. (500 Yards W. of Section 2)
S.23°E.
Brecka44 Brecka49
N.23°W.
Mellte River
Road to Ystrad fellte
G.W. Railway
SECTIONS ACROSS THE VALE OF NEATH DISTURBANCE
By A. Strahan. M.A.
Scale
500 1000 FEET
½ MILE
Wyman & Sons, Ltd. Lith. 3784. 3. 99.

: the limestone has about reached its limit of possible sharpness. (Mr. Strahan
ı Section 3, 500 yards further west, that limit has been passed,
ıd the limestone of the north side has not only broken
vay from that of the south, but has been pushed over both it
ıd some of the overlying Millstone Grit. Here relief from the
rain was obtained by overthrusting, and sharp folding became
ɔ longer necessary. The sections illustrate the development of
ı overthrust from a broken anticline.

Of the north and south faults traced last year the principal
:e the following:—

The Henryd Fault, which causes the fine waterfall of that name, by throwing Coal-measure shales down on the west against Farewell Rock on the east. Its course northwards is clearly marked to Penwyllt, where it cuts across and shifts the crest of the Cribarth anticline; southward it enters the Coal-measures near Capel Colbren and dies out.

The Glyn Corrwg Fault has been traced into the Vale of Neath at Blaen Gwrach by Mr. Gibson. It is commonly identified with a westerly downthrow of 40 yards which runs west of the Aberpergwm workings, and has been proved on the east of Onllwyn. The two faults are nearly in a line, but their identification by the miners was wholly conjectural.

The Pwllau-bach Fault has been traced from the Vale of Neath near Pentre Clwydau across Hir Fynydd to Bryn-y-Garn. Thence it runs between Onllwyn and Seven Sisters, on the east of Abercraf Colliery, and serves to account for the termination of the outcrop of pebbly grit which forms so marked a feature on the southern slopes of Cribarth. It cannot, however, be found either to the north of the Cribarth Disturbance or to the south of that of the Vale of Neath, though its throw near Onllwyn, between the two, amounts to 80 yards down to the west.

The Pen Castell Fault has already been mentioned. It would, if it kept its course across the Vale of Neath, pass near Blaen Nant-yr-Hebog, where, however, the continuous crop of the Ynysarwed Vein shows that there is no fault.

The Crynant Fault is a downthrow to the west which may be traced from the Vale of Neath across the mountain, and has been intersected in the mouth of Crynant Level. It is believed to be the Wern Plemys Fault of Swansea Vale, which has a throw of 21 yards, but it seems likely to be upwards of 60 yards at Sarn Helen, by the identification of the coal-crops on either side of it.

The Ynys-geinon Fault has been proved at the colliery of that name in Swansea Vale to be a downthrow to the west of 56 yards. Its course southwards has not yet been determined.

A number of large north and south faults near Neath and Briton Ferry were undergoing investigation at the close of the year, and will be described in next year's *Report*.

Two well-marked post-Liassic faults have been traced in the neighbourhood of Cowbridge by Mr. Cantrill. They run in a general west-south-westerly direction, one of them south of St. Hilary with a downthrow to the south, and the other, with a downthrow to the north, by Pendoylan, Welsh St. Donats, Aberthin, Cowbridge, and along the north side of Llanbleiddian Hill.

Witches' Point, at Dunraven, is a promontory of Carboniferous Limestone, capped by Lias, and owes its existence to a large reversed post-Liassic fault running in a northerly direction. The fault is admirably exposed in the cliff.

Leicestershire and Derbyshire.

(Mr. C. Fox-Strangways.) The field-work in the Leicestershire and South Derbyshire Coal-field having been completed in 1897, MR. FOX-STRANGWAYS was last year occupied in carrying on the survey to the north and east so as to complete the mapping of the surrounding ground, which will be included in a special map of the coal-field. In this manner all the area to the south of the Trent and west of the Soar has been finished. The rocks comprised within this district are Carboniferous Limestone, Millstone Grit, Permian, Bunter, Waterstones, and Keuper Marl, with a certain amount of Drift, principally on the eastern side.

The re-survey of these rocks has necessitated very considerable modifications of the old boundary-lines. The Carboniferous Limestone and the Millstone Grit remain indeed mainly as shown on the published map, but a rather larger exposure of the former has been found at Calke Abbey than is shown on that map, while a fine cliff of the limestone in the private grounds had been coloured as part of the Millstone Grit.

When MR. FOX-STRANGWAYS first commenced the revision of this ground, he thought that the different beds of grit might be traced out separately, but he afterwards found them not to be sufficiently marked in this highly cultivated district to admit of being mapped satisfactorily. Some of the stronger beds which may be traced for a certain distance help to show the general run of the strata.

Staffordshire.

The resignation of MR. DE RANCE already referred to, rendered necessary some re-distribution of the staff, in order to push forward the re-survey of the North Staffordshire coal-field and the surrounding tracts. Accordingly MR. WALCOT GIBSON was moved from Wales to undertake the continuation of the mapping of the Coal-measures. MR. WEDD, on his appointment last spring, was placed among the so-called Permian rocks on the west side of the coal-field. In the autumn, after quitting his field-work in the Highlands, MR. GEORGE BARROW was requested to revise the older Carboniferous rocks which emerge from under the coal-field on its eastern side, while MR. LAMPLUGH during the autumn undertook the examination of the red rocks along the southern border of the district. The general supervision of the whole field-work of the region was entrusted to MR. FOX-STRANGWAYS.

Yoredale series and Millstone Grit. Mr. George Barrow.) Among the Carboniferous rocks lying to the east of the coal-field MR. BARROW has made considerable progress in the re-mapping. These rocks belong to the Yoredale series and Millstone Grit, but include also a portion of the Lower Coal-measures. They essentially consist of dark shales associated with variable coloured marls. The shales generally contain plant-remains, but they are throughout marked by the occasional occurrence of

indurated and remarkably persistent bands, which are often crowded with marine organisms. These bands are frequently underlain by seams of coal, but, in the area surveyed last year they are too thin to be worked, and in some cases are merely a kind of smut. Yoredale series and Millstone Grit. (Mr. Georg Barrow.)

The shales are further characterised by the presence of a number of sandy beds, of which two specially coarse grits, lying below the Coal-measures, are known as the *First* and *Third Grits*. Some distance below these, the first group of the fine hard sandstones that distinguish the lower shales as a whole are often quarried for road-metal. Fine as these bands generally are, it is not uncommon to find in them seams an inch or two thick composed of pebbles and coarse sandy material. Still lower in the series of shales comes a grit that varies greatly both in thickness and coarseness. It is made up of grit-lenticles with irregular marly partings. MR. BARROW believes that it undoubtedly represents the Yoredale Grit of the area to the north, which PROFESSOR GREEN included in the Millstone Grit. The base-line for the Millstone Grit has been drawn at a much higher level near Stoke than in the district further north; this difference being due to the rapid thinning away and splitting of the gritty strata as they advance southwards.

A great thickness of shales, as the persistent high dips show, underlies this group of grit-wedges, and passes down into an alternation of thin fine sandstones and shales, beneath which come the impure limestones and dark shales that overlie the main mass of the Derbyshire Limestone. Even in the lowest fine sandstones, however, careful examination shows the presence at times of lines and pockets of pebbles, suggesting that they represent the dying-out southward of the Millstone Grit rather than any part of the true Yoredale series, which the so-called Yoredale series of this district does not in the least resemble. Whatever may prove to be the true age of this great mass of shales with the fine hard sandstones, it certainly seems desirable not to apply to them the term Yoredale, as has also been found advisable in the north of England. The hard shale-bands with their marine organisms will almost certainly enable us eventually to determine whether these shales are not really replaced by grits of Millstone Grit age to the north, so that the question can be left over to be decided by the results of the revision of the ground on the large scale maps.

The Carboniferous rocks had been greatly disturbed and faulted in the area between Stoke and the Churnet Valley before the deposition of the Bunter formation. One of the most remarkable features in the district is the existence of what may be termed pseudo-escarpments. Standing on the edge of the Millstone Grit we invariably look down on a valley composed of the higher Coal-measures no matter what may be the dimensions of the valley. So persistent is this feature as to convey the general impression that we are looking at a series of ordinary escarpments with lower and *not higher* beds rising up from beneath them. The singular arrangement here referred to

oredale ries and illstone rit. Mr. George arrow.)

is repeated on a finer scale in the outcrop of the great mass of limestone to the east. In almost all cases the Millstone Grit and the Limestone rise from the low-ground with a high dip, which often becomes nearly vertical and in some few cases is actually inverted. But at the top of each pseudo-escarpment the dip almost invariably flattens and is often quite low at less than 200 yards from the "edge," as this feature is often called, and is so often perpetuated in village-names such as Brown Edge, Baddeley Edge, etc.

The same singular topographical detail is to be found in Northumberland, where in almost any quarry in the Great Limestone, while the shales and sandstones are quite horizontal along the strike face, the limestone is almost always more or less violently contorted. The explanation may be that when the district was subjected to the "compression" movements that compacted the muds and sands into shales and sandstones the limestone, which is peculiarly dense, was possibly more incompressible and "buckled-up" everywhere, as the only means of enabling it to occupy a smaller space. In the Staffordshire area the grit and limestone were both deposited upon a considerable thickness of soft mud, which could be squeezed into a smaller space than the grit and still smaller than the limestone. The height of the pseudo-escarpment gives an index of the difference in compressibility of the different varieties of material. As the evidence from Northumberland would lead us to expect, the limestone, being least compressible, has given rise to higher pseudo-escarpments.

oal-easures. Mr. Gibson.)

The coal-field mapping by Mr. Walcot Gibson has led to results of considerable scientific interest, and some of which promise to be of economic importance in regard to the future development of the coal-mining industry of the region.

The Upper Coal-measures cover a wide area west of Burslem and Longton and attain there a great development. By means of the detailed surveying with maps on the scale of six inches to a mile it has been possible to subdivide this great thickness of strata into four groups which are markedly constant in lithological characters. They are distinguished by the presence of zones of limestones and shales, rich in entomostraca, which have been found to be of considerable stratigraphical value. Though seldom exceeding a foot in thickness, the entomostracan limestones are persistently developed. Some zones, consisting only of an inch or two of shale or limestone, but frequently crowded with entomostraca belonging to the genus *Carbonia*, have been traced along the strike for considerable distances. These zones have served as useful datum-lines in determining the position of some thin coals towards the base of the series, besides materially assisting in tracing the main dislocations of the district, and in showing the great probability of the existence of Upper Coal-measures at the surface to the west of the North Staffordshire anticline.

The strata are well exhibited in numerous marl-pits, quarries, road-and railway-cuttings and stream-courses, west of the Pottery

towns of Burslem, Hanley, Stoke-upon-Trent, and Longton. The best sections of the Upper Measures in the Midland Counties are to be found in this district. So far as the revision has proceeded, the following stratigraphical divisions in descending order have been recognised :— Coal-measures. (Mr. Gibso

(4) *Keele Sandstone Series*	Red sandstones and marls, calcareous breccias, fossiliferous (entomostracan) limestones. The base is a black shale crowded with the remains of *Entomostraca*, while some red marls above contain numerous plants of Coal-measure species. Thickness exceeding 700 feet, but summit nowhere seen.
(3) *Newcastle-under-Lyme Series.*	Grey sandstones, marls and shales, with four thin coals. Two bands of fossiliferous limestone (*Entomostraca, Anthracomya*, fish-remains) form the base. Thickness 250–300 feet.
(2) *Etruria Marl Series*...	Red and mottled marls with thin bands of coarse green grits near the summit and base. A *Spirorbis*-limestone occurs 80 feet below the summit at Chesterton. Thickness 700–900 feet.
(1) *Black Band Series* ...	Grey and mottled marls, the grey marl predominating. Bands of ironstone with Entomostraca, *Anthracosia* (*Carbonicola*), fish-remains. Occasional bands of grit sometimes 30 feet thick. Several thin coals. Numerous zones of limestone and shales with *Entomostraca* ; a band of limestone, constant in position (36–40 feet) above the Bassey Mine Ironstone, forms the base. Thickness about 250 feet.

The base of this great thickness of conformable measures is taken at the first limestone above the Bassey Mine Ironstone, a divisional line which has been already proposed by MR. WARD.*

In taking the Bassey Mine Limestone, as it is generally known in the district, and those at the base of the other groups as divisional lines, it must be remembered that, for the present at least, they are strictly lines of convenience. As no stratigraphical break has yet been ascertained in the entire Coal-measure series of North Staffordshire, it is necessary to fall back on arbitrary lines for dividing up the strata, and for this purpose these limestone-bands are most useful. As the work advances, it may be found necessary to include in the Upper Coal-measure, beds lower down in the system. All that is claimed for the divisions in the table here given is, that the different groups thus discriminated can be recognised over the whole area and can be satisfactorily laid down on the map.

Owing to the valuable nature of the Bassey Mine Ironstone and the marls above and below, numerous marl-pits from Longton to Burslem have been opened, so that the crop of the lowest limestone can be readily traced. For the sake of comparison these marl-pits have been measured foot by foot, and sections have been plotted on a uniform scale. Some slight lithological and palæontological grounds exist for taking the Bassey Mine Limestone as a dividing-line from the beds below. Above this

* JOHN WARD, "The Geological Features of the North Staffordshire Coal Fields." *Trans. North Staff. Inst. Min. and Mec. Eng.*, vol. x. p. 26, 1890.

limestone no workable coals occur, these being confined to the Middle and Lower divisions adopted for North Staffordshire. The Middle division is the chief repository of the ironstones and Pottery coals, the Lower division contains the best and thickest bituminous coals. The fauna above the limestone and that of the limestone itself are essentially estuarine or fresh water throughout, while marine beds occur in the Middle and Lower divisions. MR. KIDSTON* also states that the flora above the Bassey Mine Limestone is different as a whole from that below it.

Below the Bassey Mine Ironstone come the Little Row Coal and Peacock Coal. The grey marls above the Bassey Mine and Peacock Coals are locally known as the Bassey Mine and Peacock marls. The marls are extensively used in the district in the manufacture of saggers, stilts, bricks, &c.

(1) The limestone above the Bassey Mine Ironstone is very persistently developed at a uniform distance of 36 to 40 feet above the ironstone. It is a light grey or blue limestone, rich in *Entomostraca*. *Spirorbis* is fairly common, while fish-teeth and scales are also present. Resting on the limestone are three to four inches of red, grey, or black shales, containing abundant remains of *Entomostraca* associated with *Anthracomya* sp. In the marl-pits at Sneyd Green and Burslem a black calcareous shale averaging one foot in thickness and largely made up of *Entomostraca* is exposed. It is constant in its position at forty feet above the Bassey Mine Limestone, the intervening measures consisting of grey nodular marls with occasional lenticular bands of yellow grit.

In the marl-pits near Burslem several thin bands of grit, lying in grey marls, come in about fifteen feet above this black shale. The bands are seldom more than two inches thick. Some are apparently barren of fossils, others contain plant-remains, while two or more bands contain entomostracan remains associated with a small form of shell as yet undetermined. The presence of this curious little fossil on this horizon is interesting, as a similar form is abundant in some red and grey measures at Western Sprink, certainly as low down as the lower part of the Middle division of the productive measures of the district. Associated with it at Western Sprink is *Lingula*. Above these fossiliferous grits some red and grey measures, and thin entomostracan shales, are well exposed in the marl-pits at Longton, Fenton Low, Hamptons, Cannon Street, and Ladyswell. In Hamptons, Ladyswell and Cannon Street marl-pits a thin band not exceeding four inches thick of a black shale with *Entomostraca* lies a few feet above a three-foot coal. In all these pits the beds between the coal and fossiliferous shale consist of red mottled marls. It is a noticeable fact that throughout the Upper Measures of North Staffordshire the *Entomostraca* are found in strata that overlie a set of red beds or lie in the midst of red rocks, as if the presence of ferruginous solutions had been essential to the full life of these minute crustaceans.

* R. KIDSTON, "Additional records and notes on the Fossil Flora of the Potteries Coal Field." *Trans. Roy. Soc. Edin.*, 1897.

Thirty feet above the shale in the Ladyswell and Cannon Street marl-pits a shaly ironstone containing *Anthracomya Phillipsii* is overlain by a massive grit. Very much the same section is exposed in the Longton Hall marl-pit, where, however, the three inches of shale are replaced by a four-inch band of grey limestone with *Carbonia* and fish remains. How far the measures just described correspond with the Black Band series of the Silverdale district remains to be ascertained, but they appear to lie on the same horizon. Coal-measures. (Mr. Gibson

(2) The Black Band series graduates upwards into a great thickness of red, mottled, and ochreous marls with occasional bands of coarse grit and conglomerate. The grit bands are thickest and most frequently present towards the summit and base of the series. It is proposed to name these strata the Etruria Marl series, from their being extensively excavated at Etruria. From Cocknage on the south they are exposed in an almost continuous line of pits to Chesterton on the north, a distance of 8 miles. Large marl-pits have also been excavated in the Silverdale and Madeley Heath districts. The marls are used for bricks and drainpipes. In the Heath brick-pits at Chesterton, thirty feet of grey sandstone with a shaly ironstone and thin coal below it are overlain and underlain by red marls belonging to the Etruria series. The ironstone is made up of laminæ, containing numerous flattened specimens of *Anthracomya Phillipsii*. In the Metallic brick-pits at Chesterton a thin nodular band of red, marly limestone, containing large specimens of *Spirorbis*, occurs about 70 feet below the summit of the series in a thick deposit of red marl. This is the only locality in which a fossiliferous band has been found in the Etruria marls.

(3.) The next series in ascending order consists of grey sandstone, marls and shales, with four thin coals. Two of these coals towards the base are found over the whole district. The base is drawn at the horizon of two bands of limestone, which have been found to be constant in position beneath these two coals. As this subdivision of the measures is well exposed in the railway-cutting at Newcastle-under-Lyme, it is proposed to call it the Newcastle-under-Lyme series. It possesses very constant lithological characters, and is easily recognised from its position between two sets of red measures (the Keele series above and the Etruria marls below).

The limestone and fossiliferous shale at the base are invariably present. The following section, seen in the marl-pits near Longport Station, gives the characteristics of this part of the series:—

	Ft.	In.
Yellow flags and shales	20	0
Yellow shales (fish-remains)	0	6
Red shales (*Carbonia*)	1	6
Black shales (*Carbonia*, fish-remains)	2	0
Red limestone (*Carbonia*, fish-remains)	1	0
Yellow shale	0	8
Blue limestone (*Carbonia*, *Anthracomya*)	1	0
Yellow shale	1	0
Purple marls (Etruria series)	30	+

oal-easures. Ir. Gibson.)

The specimens of *Anthracomya* in the blue limestone are small in size but admirably preserved. In the red shales associated with the limestone in the road-cutting from Trentham to Whitmore, PROF. RUPERT JONES recognises *Estheria tenella* and *Carbonia salteriana*. It is believed that the Newcastle series will play an important part in future boring operations by leading to the recognition of the presence of Upper Coal-measures beneath the red rocks that conceal the Coal-measures on the west and south of the coal-field.

(4) The Newcastle series graduates upwards into a considerable thickness of red sandstones, marls, and occasional cornstone, which are well seen in quarries, railway-cuttings, and natural exposures around Keele. Hence, these strata may be conveniently distinguished as the Keele series. The area occupied by them is coloured as Permian on the published Geological Survey Map (Old Series). The fact of their strict conformability to undoubted Upper Coal-measures has been mentioned in the *Summary of Progress* for 1897 (p. 109). Fresh evidence was obtained last year to prove their intimate connection with the Upper Coal-measures, and it is a question for further investigation how far these red measures should be grouped with the Upper Coal-measures or taken as representatives of the Supra-Carboniferous rocks of Continental geologists. They certainly cannot be classed with the Permian formations of Lancashire and the N.E. Counties.

In the Newstead boring, where 550 feet of red measures consisting of alternations of red micaceous sandstones and red marls, overlying the Newcastle series, were pierced, the base is provisionally taken at a black and red shale (with *Carbonia*, Fish-teeth, *Pelecypoda*), which has not been met with at the surface of the ground, though the red sandstone with cornstone bands, a few feet above, is seen in many sections. The railway-cutting near Keele Park Station exposes a good section of red sandstones and marls, in the midst of which lies a band of black limestone one foot thick, which has yielded specimens of *Carbonia* and *Spirorbis*. In Dunge Wood a cream-coloured limestone, with *Carbonia* and *Anthracomya*, is associated with red marls and sandstones, but the ground is here traversed by faults, and this limestone may be the seam that is found at the base of the Newcastle series.

West of Madeley and Ashley MR. WEDD finds these red measures coming to the surface from under the Trias in the Willoughbridge and Mucklestone districts, where they consist of dark-brown and pink-brown, fine-grained felspathic sandstones. Marls are there seldom seen, but the same observer thinks it probable that red marls occupy some of the gently sloping ground. Near Willoughbridge he has come upon a dark limestone with *Carbonia* associated with crimson marl that has been formed from the weathering of a red felspathic sandstone. While he regards this limestone as undoubtedly in place, he has also found blocks of a hard crystalline and greyish buff limestone lying on the floor of a disused quarry near Sidway Hall, east of Willoughbridge, which no doubt have come from a seam that was dug out

of the pit, though not now visible. No organisms were found in the blocks. Coal-measures. (Mr. Gibson)

The red colour of the Keele series is no doubt original. Throughout the entire Coal-measure period, over what is now the area of North Staffordshire, red deposits were being laid down at intervals. The red marls and limestones of Western Sprink and the red sandstone above the Ten-foot coal are scarcely distinguishable from those in the Keele series.

In Spring Valley, Trentham Park, a breccia is exposed which is made up of small angular fragments of Carboniferous Limestone in a red matrix. It is unconformably overlain by Pebble-beds of Bunter age. The field-work last year was not carried far enough to determine the horizon on which this breccia lies.

An interesting specimen of an iron-ore was discovered by MR. GIBSON towards the close of the season in the Fenton Park Clay Pits. It is a greyish ore, occurring in bands and nodules in grey marl. An analysis by DR. POLLARD shows:—

(E. 3214.)

FeO	49·40
Fe_2O_3	·08
Al_2O_3	1·56
P_2O_5	·24
MnO	·82
NiO, CoO	trace?
CaO	·85
MgO	1·36
CO_2	31·87
S	*trace (as FeS_2).
Organic matter	·47
Residue ignited	11·68
Water at 105°	·23
Water on ignition	1·20
	99·76
Ignited insoluble residue :	
SiO_2	7·22
Al_2O_3	4·00
Fe_2O_3	·41
	11·63
Iron total amount	38·7%

MR. TEALL states that "the rock is composed almost entirely of spherulites of siderite. The spherulites measure from 1 to 1·5 mm. in diameter and are usually composed of 8 or 10 individual crystals. They are often stained brown at their margins in consequence of the decomposition of the siderite and the oxidation of the iron. Sometimes the spherulites are in close contact with each other and sometimes there is a small quantity of brown interstitial matter. The insoluble residue consists of a very fine mud. The rock is a sphero-siderite."

The specimen was obtained from an horizon between the Deep Mine Ironstone and Knowles Coal at 79 yards above the latter.

[illegible] Staffordshire may [illegible] fresh- [illegible] they were laid [illegible] constant [illegible] beds of [illegible] in the [illegible] the [illegible]

[illegible] upper part of the [illegible] may [illegible] the base [illegible] of red [illegible] red strata [illegible] Upper [illegible] the west [illegible] Heath and [illegible] present [illegible] the Bunter [illegible] Malkey [illegible] that the [illegible] Staffordshire [illegible] red rocks [illegible] body [illegible] below [illegible] coals and [illegible] might have been [illegible]

[illegible] the areas having [illegible] to [illegible] and Black [illegible] their respective [illegible]

[illegible] coal-field has [illegible] These take the [illegible] of the folds [illegible] normal faults [illegible] N.N.W. and S.S.E. [illegible] is powerful faults [illegible] east and west [illegible] large [illegible] trend and of small [illegible]

No conclusive [illegible] the relative ages of some of these faults. [illegible] suggest that the Bunter formation [illegible] North Stafford-shire anticline. [illegible] large [illegible] to the east, trending N.N.W. [illegible] more than ten miles, is certain [illegible] seem to be all the more powerful N.N.W. [illegible] large

fault, trending nearly N.E. to S.W., appears to be connected with a fault seen at Madeley Manor, which brings red Upper Carboniferous rocks overlain by Bunter beds against strata as low down as the Etruria Marls. The same fault apparently runs underneath the drift deposits of Madeley and appears at Bar Hill Farm, where some highly inclined Bunter Pebble beds are faulted against red Upper Coal-measures. The fault is again lost beneath superficial deposits to Winnington. From this point to Mucklestone a fault with a downthrow to the west has been traced by MR. WEDD. At Normacot an east and west fault with a throw estimated at 250 yards may affect the Trias, but this point remains to be settled. Coal-measures. (Mr. Gibson

In any attempt to classify the faults and folds of the North Staffordshire Coal-field it should be borne in mind that the Coal-measure period was one of gentle oscillations, as shown by the recurrence of marine beds amidst those of estuarine origin in the Middle and Lower Coal-measures. During the vast interval between the time of the highest Carboniferous strata and that of the Trias there may have been many geographical changes in the region, but in the end the elevatory forces gained on those of depression and culminated in the Bunter. The connection of the faults and folds with these upward movements and with the downward movements during which the Mesozoic rocks were deposited remains for future investigation. There is some evidence in support of the idea that the Swynnerton Dyke and some of the N.N.W. faults may be of Tertiary age.

Lorne.

In the last two annual statements of the work of the Geological Survey* reference has been made to a small patch of red marls, sandstones, and conglomerates which have long been known to occur at the Bridge of Awe. These strata have been generally regarded as belonging to the Old Red Sandstone, though no fossils had ever been obtained from them. As some of their beds seemed not unlikely to yield organic remains, advantage was taken of MR. TAIT'S renewed search for further ichthyolites among the Lower Old Red Sandstones of the Oban district to subject these strata to a closer examination. As already stated, his labours were rewarded by the discovery of a number of organisms which suffice to show that the strata in question do not belong to the Old Red Sandstone but to the Carboniferous system—a fact of the greatest interest in regard to the geological history of the West Highlands.

The specimens obtained by the fossil-collector included a small number of fossil plants, which, however, were unfortunately in a fragmentary state. Such as they are, they have been submitted to MR. KIDSTON who finds that they consist of stems, rootlets, a fern rachis, and a calamite stem, which last he (Mr. Peach

* *Annual Report* for 1896, p. 55 ; *Summary of Progress* for 1897, p. 85.

ach.) thinks is referable to *Asterocalamites scrobiculatus*, Schl. While of opinion that the plants have a Calciferous Sandstone (Lower Carboniferous) facies, he is certain that they cannot belong to the Lower Old Red Sandstone. A point in favour of the Carboniferous age of these strata is that a small patch of plant-bearing Carboniferous rocks was detected by PROFESSOR JUDD* on the east shore of the Sound of Mull near Ardtornish, a distance of only 20 miles to the W.N.W. of the strata at Bridge of Awe.

Another piece of evidence in favour of the Lower Carboniferous age of the Bridge of Awe beds is afforded by the occurrence of the cast of a small modioliform shell on one of the specimens with rootlets (T. 3257). This form, though badly preserved, is almost identical with some varieties of *Modiola Macadami*, Portl., one of the commonest shells of the Cement-stone group of the Lower Carboniferous series in Fife, Liddesdale, and the North of Ireland. Three varieties of the shell are figured in Portlock's "Geology of Londonderry and Tyrone."

nas- In consequence of this discovery MR. KYNASTON re-examined the locality in order to revise his mapping of the ground. The result of this further scrutiny was to convince him that the strata in question at the Bridge of Awe are the highest to be seen in the district, and that they are not overlain by any of the Lorne lavas as he had previously supposed. On the other hand, it might have been expected that any much younger group of strata would have been separated from the Lower Old Red Sandstone and its lavas by a marked unconformability. On the banks of the Awe, however, MR. KYNASTON has traced a perfectly conformable succession from the lavas to the sediments. The lowermost strata of the latter overlie andesitic lavas, apparently identical in character with the normal type of the district, and moreover these lower beds contain a very distinct admixture of volcanic material, the conglomerate frequently showing fragments of andesite besides the numerous quartz pebbles. But possibly this lower band of conglomerate indicates an unconformability, and the volcanic material in it and in the reddish sandy shales succeeding it was derived by erosion from the underlying lavas. MR. PEACH has suggested that there may be in this district lavas of Carboniferous, besides those of known Lower Old Red Sandstone age. He argues that there must be either a great stratigraphical break at the base of the sediments, the tuff-like beds in which were derived from the mechanical trituration of the much older lavas underneath, or a passage upward from the volcanic into the non-volcanic rocks, in which case there would be evidence of a second and younger volcanic series like that of the Campsie Fells, and an unconformability would probably be found to exist between this series and the older lavas of Lorne.

MR. KYNASTON, however, has been unable to discover any sign of a marked break in the continuous succession of lavas in the neighbourhood. He believes that there is here but one volcanic series, that of the Lower Old Red Sandstone, and that there exists

* *Quart. Journ. Geol. Soc.*, vol. xxxiv., pp. 684–685.

there a small outlier of Carboniferous sedimentary rocks which overlie the eroded andesitic lavas of Lorne where these abut against the great dislocation of the Pass of Brander at Bridge of Awe. (Mr. Kynaston.)

Isle of Arran.

In the *Summary of Progress* for 1897 the existence of true Coal-measures in the Isle of Arran was announced, and lists were given of the fossils on the evidence of which the identification of strata of that age had been made. During the past year the collections of fossils have been more carefully examined. A portion of the series of fossil plants from the Calciferous Sandstones of the northern part of the island has been gone over by MR. KIDSTON. His examination shows that the plants from these strata have a strong Lower Carboniferous facies. The most conspicuous and common plant is *Lepidodendron veltheimianum*. From Locherim Burn, the locality from which PROFESSOR IVISON MACADAM obtained the plants, a list of which appears in the *Trans. Geol. Soc. Edinburgh*, vol. v. p. 316, he records the presence of *Asterocalamites scrobiculatus*, the same form which he thinks also occurs at Bridge of Awe.

A special collection of plants was gathered from the volcanic zone of the Calciferous Sandstone at the locality near Laggan Shepherd's house on the east coast, where MR. WÜNSCH obtained specimens of plants exhibiting internal structure in an exceptionally good state of preservation, as described by the late PROFESSOR WILLIAMSON. The collection thus made, consisting of plants not in a very good state of preservation, was submitted to MR. KIDSTON, who believes one of the species to be *Lepidophloios wünschianus*, Williamson (sp.), described by WILLIAMSON by mistake as a *Lepidodendron*. From the finer tuffs of this locality he records the occurrence of a species, *Sphenopteris (Rhodea) patentissima*, new to Scotland, the only other British record of it being from the north of England.

City of Edinburgh.

Owing to the widening of the North Bridge in Edinburgh it became necessary that the street leading south from it should be also widened, and this has necessitated the pulling down and rebuilding of the street. The west side having been taken by the proprietors of the "Scotsman" newspaper, extensive excavations for the foundations of their offices have been made beneath what was the old Market Place, revealing a fine section of shales, mudstones, and sandstones resembling many of those so common near the base of the Cement-stone series in the South of Scotland. The strata dip at 10°–15° to the E.N.E. MR. DUNCAN, one of the attendants in the Museum of Science and Art, found in this section a dark seam which contained fragments of plants, *Spirorbis* and ostracods.

As this bed is apparently the lowest from which fossils have been obtained among the rocks that underlie the city, it was thought desirable to search it for further organic remains. Mr. Tait therefore made a collection from it. The fish remains in this collection were submitted to and determined by Dr. Traquair. The Ostracods were named by Mr. J. W. Kirkby. The recognisable remains of plants comprise *Adiantites lindsæformis* (now known as *Rachopteris inequilatera*), *Stigmaria*, and various fern-stems. The worms are represented by *Spirorbis carbonarius* and *S. helicteres*, still attached to some of the plant-remains. The Ostracods are *Leperditia subrecta*, *L. Okeni*, *L. wrightiana (?)*, *Kirkbya spiralis* (abundant), *Argillœcia œqualis*, *Aglaia cypridiniformis (?)*, *Bythocypris sublunata (?)*. The higher crustacea are represented by the portion of a carapace of *Anthrapalæmon*, while fragments of scorpion-skin show the presence of arachnids. Fishes are represented by scales of *Rhizodus* and of a palæoniscid fish.

Mr. Kirkby, in referring to the ostracods examined by him, says:—"By far the most common form is *Kirkbya spiralis*; it is very abundant. All the species are essentially Lower Carboniferous forms; and as a group are characteristic of the lower half of the Cement-Stone Series rather than the upper. . . . . The doubtful things are always met with at low horizons, and had the lot been found in Fife it would not have been higher than the Billow Ness beds."*

This palæontological evidence is quite in conformity with the stratigraphical position assigned to these Edinburgh strata by the Geological Survey.

Permian.

The chief feature in the revision of the "red rocks" of Central England during the past year has been the change made in the area of the so-called "Permian" formations. As already pointed out (p. 126), large tracts of red sandstones and marls in North Staffordshire, hitherto coloured as Permian, prove to be really an upper part of the Coal-measures into which they pass down conformably. And the same change will no doubt require to be made throughout the Midlands as the revision advances.

cester-re. r. Fox angways.)

In continuing his field-work along the north of Leicestershire and south of Derbyshire Mr. Fox Strangways has had to modify considerably the older mapping, chiefly in respect to the red rocks. In the district of Ticknall, for example, he has been unable to find evidence for any of the N.E. faults which have been shown to the west of that place; hence the area of the Permian beds (which are quite distinct from the strata now relegated to the Carboniferous system) is considerably more extensive than it has hitherto been represented to be. Thus the

* *See* J. W. Kirkby, "Zones of Marine Fossils in the Calciferous Sandstone Series of Fife." *Quart. Journ. Geol. Soc.*, vol. xxxvi. (1880), pp. 559–590.

narrow strip of Permian strata mapped to the north-west of the village of Hartshorn really extends down the whole length of the Foremark Valley until it is lost under the alluvium of the Trent at Milton. The other patch of the same marls and breccias shown on the published map at Ingleby is found to come south to the Carboniferous Limestone at Ticknall, on which it lies unconformably. The structure of the ground between Ticknall and the Trent is certainly rather obscure, and different explanations of it have been proposed. Mr. Fox Strangways has obtained some fresh evidence which may help towards a solution of the difficulty. The shales which have been mapped as Coal-measures between Ingleby and Coppy Hill are probably of Lower Carboniferous age. They dip regularly under the fine escarpment of Millstone-grit in which the strata have a distinct inclination of from 5° to 10° towards north-east. Leicestershire. (Mr. Fox Strangwa

In previous *Annual Reports* of the Geological Survey reference has been made to the newer red rocks of the island of Arran, regarding the true geological position of which no definite evidence has yet been obtained. Mr. Gunn was able last year to prolong his mapping of these strata at the northern end of the island. Near the Cock of Arran a detached outlier of them consists of false-bedded bright-red sandstone (like that of Corrie), about 1,000 feet in thickness, and of beds of conglomerate which mainly overlie the sandstone. The conglomerate resembles that exposed in Brodick Bay, and lies probably on the same horizon. As the beds dip seaward numerous landslips have occurred and the hillsides show many gaping fissures. Arran. (Mr. Gunn

On the west side of the island similar false-bedded red sandstones occur in the Machrie Water and to the northward of it, but there seems to be no equivalent there of the conglomerates. In this part of the island the younger formation appears as if quite conformable to the Old Red Sandstone below it, so that it is not easy to say exactly where one formation ends and the other begins. The gently inclined newer Red Sandstone of the Machrie Water when traced up the stream gradually increases in the amount of its dip from 10° to 30° or so, as far as the outcrop of a conglomerate which may or may not be part of the Old Red Sandstone. A similar difficulty occurs in the section in the Machrie Burn and on the coast opposite Auchagallon. While it is to be hoped that diligent search will result in the discovery of some fossil evidence which may settle the exact boundary-line, there is meanwhile no doubt whatever about there being here two distinct formations.

Trias.

Considerable tracts of the various subdivisions of the Triassic system have been re-mapped during the past year, chiefly in the Midland counties, but partly also in South Wales. South Wal (Messrs. Tiddeman and Cantri

On the south side of the South Welsh coal-field it has been necessary to survey an interrupted strip of Upper Triassic rocks

ıth Wales. esars. ldeman l Cantrill.)

which intervenes between the edge of the Carboniferous formations and the coast-line of the British Channel. During the past year this survey has been nearly completed by MESSRS. TIDDEMAN and CANTRILL. One of the conspicuous features of these strata is the occurrence among them of a group of conglomerates or breccias chiefly made up of fragments of Mountain Limestone—the so-called Dolomitic Conglomerate. In his recent field-work MR. CANTRILL traced these conglomerates and breccias to the east of Cowbridge; but west of that town the Trias disappears and littoral limestones of Liassic age rest directly on the Carboniferous rocks. Further on again, however, the Trias reappears, and MR. TIDDEMAN has mapped a number of separate areas of it. Of the pebbles included in the conglomerate and breccia, Carboniferous Limestone forms by far the largest proportion, but pieces of chert and occasionally of sandstone also occur. In some parts, as near Porthcawl, marls are almost absent but in others, as near Pyle, they make up a greater thickness than the conglomerates. As explained in previous *Reports*, the marls and conglomerates were contemporaneously thrown down, the latter being merely irregular accumulations of débris at the foot of the Triassic shore-cliffs. The occurrence of foot-prints in the conglomerates, as recorded by PROF. SOLLAS,* proves that the deposit was spread upon a foreshore that was occasionally dry. The finer bands of conglomerate and the marls not infrequently show ripple-marks. Near Porthcawl a cave in the Carboniferous Limestone is noted by MR. TIDDEMAN as having been filled with Triassic gravels, marls, and travertin, and as being therefore of Triassic age.

At Sutton the conglomerates become yellow, and are with difficulty distinguished from Liassic basement-beds, but usually when the upper part of the series is complete it consists of marls, and then runs up without any break into the Rhætic beds. Hæmatite has been found below these conglomerates at Rhythin, but attempts to work it appear to have met with no success.

The mapping of the Rhætic beds from Cowbridge westwards by MESSRS. TIDDEMAN and CANTRILL has given prominence to the fact, not unknown previously, that this formation completely changes its lithological aspect in passing from the east to the west end of the Vale of Glamorgan. At Penarth it consists of shales with thin seams of limestone, but west of Cowbridge it includes thick beds of white quartz-sandstone, which increase westwards until shales become quite subordinate. The upper strata of the Keuper series undergo a corresponding change in the same direction, so that it becomes increasingly difficult to recognise the base of the *Avicula contorta* shales, which served well for a base-line to the Rhætic formation at Penarth.

This development of quartz-grit takes place in that area in which the Secondary rocks pass on to the Millstone Grit of the north side of the great Cardiff and Cowbridge pre-Triassic anticline. From the poor development of the lower red portion of the Keuper Marls it may be inferred that this part of the area stood

* *Quart. Journ. Geol. Soc.* vol. xxxv, p. 511.

above water during much of the Triassic period. That the Millstone Grit formed a large part of the shore-line of the uppermost Keuper and Rhætic is obvious. Here, therefore, we find the source of the quartz-sand, and the explanation of the close lithological resemblance of the Secondary sandstone to Millstone Grit. South Wa (Messrs. Tiddeman and Cantri

As neither the stratigraphy nor palæontology of the Rhætic strata had been fully worked out by the end of last year, an account of them is reserved for a subsequent *Summary of Progress*.

In Mr. Fox Strangways' area already referred to, he has found that the Waterstones cover a much larger area than has hitherto been supposed. They cap most of the high ground about Bretby Park, Repton Shrubs, and Foremark, the pebble-beds only coming out along the valleys. The hill at Foremark Park Farm is not Millstone Grit but Waterstones, as has been shown by Mr. Horace T. Brown. The Waterstones also stretch further on the east side of the anticline. They are not cut off by the Breedon-Osgathorpe fault, which is pre-Triassic, but extend down the whole length of the valley to the north-east. Leicestershire and Derbyshir (Mr. Fox Strangwa

The Keuper marls will remain nearly as represented on the published map, but their line of boundary is in many places considerably modified, with the result of reducing the area covered by these marls.

In the revision of the North Staffordshire coal-field it has been necessary to include such portions of the surrounding Triassic districts as were required for the completion of the coal-field maps. Mr. Gibson and Mr. Wedd have in this way revised the Triassic areas lying along the western borders of the district. Mr. Lamplugh has been engaged in those on the south side, while Mr. Barrow has taken those to the east. North Staffordsh (Messrs. Barrow, Lamplugh Gibson, and Wedd

Messrs. Gibson and Wedd, in the ground examined by them, have found the lower portion of the Triassic series to present some difficulty in mapping, either from complicated structure or from the thick cover of drift deposits under which so much of the older formations is buried. Thus they have not been able to separate the Upper Mottled Sandstone from the Bunter Conglomerate. In the absence of Lower Mottled Sandstone, the Bunter formation, to the west of the Potteries, may be regarded as consisting of the middle division only. In some cases, as at Beech, the Upper Mottled Sandstone is absent, but in the neighbourhood of Maer and Stableford a brick-red mottled sandstone underlies the Keuper series. The ground, however, is very obscure and evidently traversed by faults.

The most important alteration in the former mapping of the Trias in this part of the country must be made near Pipegate, where Mr. Wedd has detected Keuper sandstones in a quarry at Dorrington, in a tract hitherto coloured as Upper Mottled Sandstone.

The base of the Keuper formation is a hard coarse-grained brown and white sandstone, with scattered quartz-pebbles. It rests unconformably on mottled red sandstone. At Bearstone the basal beds have been observed by Mr. Wedd to include a

light red and white sandstone with characteristic starlike markings standing out on the weathered surface. The Keuper sandstone consisting of pink-brown and white sandstone, with marl partings, has been extensively quarried at Beech, Chapel Chorlton, and Dorrington.

The bottom of the Keuper Marls has been drawn at the horizon where thin fine-grained flags, with pseudomorphs of rock-salt, overlying Waterstones appear. Usually a small rise in the ground marks this horizon. The Keuper Marls are seen to overlap the Bunter at Ashley, Maer, and a little south of Beech.

MR. LAMPLUGH'S attention was given to the development of the Trias to the south of the coal-field, where from the scarcity of rock exposures few detailed observations are possible. The ground is underlain by the Keuper Marls, the bottom of which was met with in the north-western part of the district between Rocester and Upper Tean, where the small tract of Lower Keuper Sandstone at Hollington was examined, as well as the ridge of Bunter Conglomerate to the westward of that place. The downward sequence in this district agrees very closely with that observed by MR. STRAHAN in Cheshire.*

As in Cheshire, the Keuper Marl here passes down gradually into thin flaggy alternations of marl and soft sandstone (Waterstones), and these are underlain by the irregular Lower Keuper Sandstone, which occurs in thick beds, often strongly cross-bedded and sometimes pebbly, with thin marly partings. On the published map this sandstone is not separated from the Waterstones, but their partition, on the lines adopted by Mr. STRAHAN in the neighbouring county, may be found desirable.

As was pointed out by that officer, the lithological characters of the sandstone link it more closely with the underlying Bunter Conglomerate than with the overlying Waterstones and Marl. This question will be more fully considered as the revision of the Triassic areas of the Midlands is carried on.

In mapping the tracts of Triassic strata to the east of the North Staffordshire coal-field, MR. BARROW has been led to make some observations bearing on the age of the chief movements by which the structure of the region has been determined. These movements have long been known to be of earlier date than the Bunter formation, which rests with a violent unconformability on the disturbed Carboniferous strata. Not a trace of any faulting or disturbance was detected in the ground surveyed by MR. BARROW last year. At the same time he has noted the pitted pebbles of the Bunter beds as evidence of compression and movement of much later date.

As in South Wales, the pre-Triassic land surface appears to be still preserved under the younger formation. The present topography of the Carboniferous rocks is thus probably not greatly different from that which they possessed in the Bunter epoch. Patches of Bunter beds have been met with in isolated positions

* *Geol. Mag.*, Dec. 2, vol viii., p. 396 (1881), and in the *Geological Survey Memoir on the Neighbourhood of Chester* (1882).

in several parts of the district, even on the hill tops. The broader parts of the Churnet Valley appear to be the old hollow of the Bunter period with a part of the Triassic deposits denuded out of it. (Mr. Barrow

The occurrence of red sandstones and breccias lying conformably beneath the Lias of the west coast of Scotland has now been recognised in a number of places, particularly in the district of Strath in Skye and in the island of Raasay. These strata, though unfossiliferous, are regarded as probable equivalents of the uppermost Trias or Rhætic group of England. Last summer, during a yachting cruise around the coast of Skye, the DIRECTOR GENERAL was joined for a day by MR. HARKER, who was then stationed between Glen Sligachan and Loch Scavaig. While boating along the northern shores of the Sound of Soa, they were fortunate enough to light upon a hitherto unobserved patch of the same group of strata, whereby the area of the Triassic rocks is advanced considerably further to the west. Skye. (Director-General and Mr. Harker.)

The Torridon sandstones with the overlying unconformable Tertiary bedded basalts come out in a picturesque range of cliffs along the west side of Loch Scavaig, and sweep round under the huge gabbro masses of the southern Cuillins into the Sound of Soa, as far as a small stream that comes down from the flanks of Garsven, opposite the little harbour in the island of Soa. Where the Torridon sandstones begin to descend to the beach, a band of reddish breccia was observed to come in between them and the bottom of the overlying bedded basalts. This breccia descends to the level of the sea, where it forms a group of ledges and low cliffs. Partly red and partly grey, it is highly calcareous, and passes upward into a sandy limestone. The stones are both angular and rounded. Though to a large extent derived from the adjacent Torridon sandstones, they include also a great number of pieces of Durness limestone and chert.

These breccias, which so closely resemble those of Strath, pass upward into grey and reddish banded and nodular limestones and dark grey shales, possibly indicating the very bottom of the Jurassic series. Unfortunately the rest of the sedimentary succession has been concealed under the vast volcanic accumulations of the district. No fossils were noticed, but during the brief time at the disposal of the observers, there was no opportunity to search even the more promising bands.

At a later period, while the yacht was passing between the islands of Raasay and Scalpa, the DIRECTOR GENERAL observed from a distance some shore ledges obviously different from the prevailing chocolate-red Torridon sandstone. On landing at the place which projects at the extreme north point of Scalpa, he found a small islet, consisting of brecciated conglomerate and red sandstone. As in the Sound of Soa, the enclosed stones consist largely of Durness limestone and chert, as well as of Torridon sandstone, gneiss, and other rocks. The same strata stretch for about a quarter of a mile along the shore, cut through by basalt-dykes. They are faulted against the Torridon sandstones, on which they may also be seen to rest unconformably.

There can be no doubt that they are a prolongation of the precisely similar strata which in the immediately adjacent island of Raasay are seen to emerge from under the Lias.

JURASSIC.

South Wales. Messrs. Tiddeman and Cantrill.)

Besides the Triassic rocks, the lower parts of the great Jurassic series occupy a number of detached areas in the strip of low ground which intervenes between the southern edge of the South Wales coal-field and the shore of the Bristol Channel. During last year further progress was made by MR. TIDDEMAN and MR. CANTRILL in the revision of these areas. Their mapping affords illustration that not only does the Rhætic group overlap the Keuper, but that the Lias overlaps both, while at the same time the lowest zones of the Lias are themselves overlapped by higher Liassic strata. It thus happens that not only each formation, but each zone in turn takes locally the position of a basement-bed, and assumes a littoral character, totally different, as a rule, from its normal aspect. In no part of the series is this change more marked than in the Lias, for the massive, tufaceous and more or less conglomeratic shell-limestones of that formation in its near-shore condition, present at first sight but little in common with its usual thin alternating limestones and shales. Six varieties of Liassic shore-deposits have been noted by MR. TIDDEMAN:—

1. Conglomerate, the most obvious beach of all.
2. A consolidated gravelly sand made of fragments of the older rock, together with broken Liassic shells and corals.
3. A similar rock, with larger angular fragments of the old rock sparsely scattered in it.
4. Tufaceous rocks with or without included shells, and often containing fragments or pebbles of the older rock.
5. Oolitic limestone.
6. Reefs, of which 50 per cent. consists of coral growth.

The most extensive overlapping by the Lias takes place along the crest, and to the south of the Cardiff and Cowbridge anticline. Thus MR. CANTRILL finds the Lias creeping across the Keuper and Rhætic groups between Llandough and Llanbleiddian, and resting on Carboniferous Limestone at Cowbridge and Penllin, while it holds the same relation to the older rock in MR. TIDDEMAN'S ground south of Bridgend and in the Southerndown cliffs.

The stratigraphical relations of these formations to one another repeatedly show that the coast-lines of older Mesozoic time were diversified by eminences which, during the subsidence of the region, passed through the successive stages of promontories, peninsulas, and islands before they were all finally submerged in the Liassic sea. Denudation has disinterred many of these buried crags and exposed to view the Lias resting upon their tops, or the Rhætic and Keuper piled against their feet, according to the depth to which the process of uncovering has reached. It may be noted

that the principal eminences consisted then, as now, of portions of the Carboniferous Limestone escarpment. South Wale (Messrs. Tiddeman and Cantrill

It follows from what has here been said, that the base of the Lias, at any point where it rests on the limestone, may not be the true base of the formation, and, as a fact, MR. TIDDEMAN never finds the lowest band of the Lias, in which *Ostrea* abounds, except where the Rhætic group is present beneath. In such cases, the abnormal character of the local basement-bed makes its zonal identification extremely difficult.

From Oxford as a centre, MR. J. H. BLAKE is engaged in the revision of the mapping of the Jurassic formations, together with that of the superficial accumulations. Various modifications have been found necessary in the published maps. Some important information has been obtained from a boring made for MESSRS. HANLEY AND CO., at the City Brewery, Oxford, by MESSRS. LE GRAND AND SUTCLIFF, to a depth of 439½ feet. The Jurassic rocks have been pierced down to the Lower Lias, and some interesting features in them have been brought to light, chief among which perhaps is the proof of the existence of the Upper Estuarine series and Inferior Oolite beneath Oxford, and the absence there (unless faulted) of the Upper and Middle Lias. MR. BLAKE, from a careful examination of the cores and from specimens preserved, has compiled the following section of the strata passed through in the bore:— Oxford. (M J. H. Blake

Valley Gravel, &c.	30	feet.
Oxford Clay	210	„
Cornbrash	17	„
Forest Marble	32¾	„
Great Oolite	88	„
Upper Estuarine Series	28½	„
Inferior Oolite	16¾	„
Lower Lias	17	„

CRETACEOUS.

The investigations of the Geological Survey during the past year among the Cretaceous formations have extended from Dorsetshire to Norfolk. They have largely consisted in the examination of special questions connected with the completion of descriptive memoirs. But at the same time the revision of the mapping of these formations has advanced steadily in the course of the re-survey of the southern counties for the completion of the agronomical map of England.

From Maiden Newton as a centre MR. HINXMAN, who was temporarily transferred from Scotland for the purpose, traced the outcrop of the Melbourne Rock and Chalk Rock that mark respectively the limits of the Lower and Middle Chalk; and mapped the superficial deposits of clay and gravel that rest on the chalk. Dorsetshire (Mr. Hinxman.)

The calcareous grit which forms the top of the Upper Greensand in South Dorset, with an average thickness of 6–9 feet, passes to the north of Maiden Newton into a glauconitic gritty sandstone. Between Evershot and Rampisham this bed is only from one to two feet thick, and in places appears to be altogether absent.

Dorsetshire. (Mr. Hinxman.)

The depression of the chalk plateau west of the Frome Valley, in which lies the village of Compton Valence, is occupied by an inlier of Upper Greensand and Jurassic Clay, these rocks being brought up on a dome with a qua-qua-versal dip. At the western end of the area, the Upper Greensand dips west-north-west at the comparatively high angle of 22°, but at the eastern extremity the beds are inclined to the east at a low angle. The centre of the dome is occupied by stiff blue and yellow clays, which may belong either to the Fuller's Earth or Oxford Clay. There are few good exposures of these clays, and no fossils have yet been detected in them. Another small inlier of the Upper Greensand, let down on the east by a cross-fault, has been mapped a quarter of a mile further to the north.

Wiltshire, Hampshire, and Dorset. (Mr. Bennett)

Further to the east, on the margin of Dorset and in the counties of Wiltshire and Hampshire, MR. BENNETT, working from Salisbury as a centre, in continuation of his previous survey, has completed an additional area of the revision of the Cretaceous rocks. The chief feature of novelty in his examination has been the detection of two previously unrecognised inliers of Upper Greensand at Bower Chalk and Alvediston, and of two new outliers of Reading Beds (sands and pebble-beds) at Pentridge, and to the north-west of Breamore. Some other remarkable peculiarities have been noticed by the same observer on the Chalk Downs near Cranborne Chase. The main escarpment of the Chalk faces the north at Win Green and Winkelbury Hill, and rises to a height of a little more than 900 feet. Along the dip-slope towards Tollard Royal the Chalk has been deeply excavated and two irregular inliers of Middle and Lower Chalk have thereby been exposed. The larger of these inliers occurs between Ashmore on the south-west and Win Green and Winkelbury Hill on the north. It stretches so near to the crest of the Chalk escarpment that only a narrow ridge (50 yards wide of Upper Chalk and 250 yards wide of Middle Chalk) separates that escarpment from the steep scarp formed at the northern end of the inlier above Ashcombe Farm. There indeed the head of the combe is formed by ground which slopes steeply from an elevation of 800 and 900 feet along the crest of the escarpment down to 500 feet around a broad indented hollow which contracts southwards as it merges into Ashcombe Bottom. Equally striking features occur in the south-western portion of this straggling inlier at Quarry Bottom. These dry chalk valleys, like those in Sussex, were probably formed in the manner explained by Mr. C. Reid.*

Oxfordshire. (Mr. Blake.)

Still further along the strike of the Cretaceous formations, MR. J. H. BLAKE has been engaged upon the revision of the rocks in the district around Oxford. Some alteration has been found necessary in the published maps in regard to the boundary-lines of the Iron Sands (Lower Greensand) which cap the irregular outlier of Portland Beds that lies to the east and south-east of the city. The two most noticeable corrections are perhaps that the

* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364.

outcrop of Portland Beds between Littleworth and Wheatley has been continued instead of being masked by an overlap of the Iron Sands upon the Kimeridge Clay, and that what was shown as a small outlier of Iron Sands has been joined on, as it really is, to the main mass at Horsepath. South of Waterstock, in the revision of the boundary-lines of the Gault and Lower Greensand, the outcrop of Lower Greensand has been shown beneath the Gault, instead of its being hidden by an overlap of the Gault upon the Kimeridge Clay, as it is represented with a doubtful line on the published map. Oxfordshire. (Mr. Blake.)

The preparation of a Memoir on the country bordering the Wash rendered necessary some further critical examination of certain portions of the Cretaceous series of Norfolk. The relationship of the Lower Cretaceous rocks of that county to the better known deposits of the same geological period north of the Wash has not hitherto been satisfactorily established. Accordingly, Mr. Lamplugh, whose close personal acquaintance with the Yorkshire and Lincolnshire types peculiarly fitted him for the work, was detailed to make the required study. Norfolk. (Mr Lamplugh.)

As the area forms the chief link between the well-developed marine sequence of the Lower Cretaceous Series of the north-east of England, on the one hand, and the scattered and incomplete sections of these rocks in the Eastern Midlands and the widely different strata of the Wealden district, on the other hand, the correlation is of much importance to the student of the Lower Cretaceous rocks of England.

It was hoped that a re-examination of the chief sections, in the light of recent researches farther north, might serve to establish the correlation; and though the paucity and poor state of preservation of the fossils of these deposits in Norfolk, and the peculiarly local facies of such as do occur, have hindered definite conclusions on some points, it is believed that sufficient evidence has now been obtained to indicate, at any rate, the broader outlines of the correlation. These results have been incorporated in the Memoir on Sheet 69 which is now in the press, but may be briefly recapitulated in this *Summary* of the year's work.

In the northern part of Norfolk the Lower Cretaceous Series consists of three distinct lithological divisions—the Lower Sands, to which the term Sandringham Sands has been applied in the Memoir just referred to; the Middle Clays, or Snettisham Beds of the same Memoir; and the Upper Ferruginous Sands or Carstone.

The middle clayey division, however, dies out southward, and the Upper and Lower Sands have then usually been considered inseparable. But it has now been found that before the Snettisham Clay has entirely disappeared, its lower portion is replaced by an irregular band of concretionary ferruginous sandstone, containing numerous marine fossils in the condition of obscure casts, and that this band can be followed after the clay has died out, so that the line between the Carstone and the Sandringham Sands is traceable throughout the district.

In the Sandringham Sands the only fossils which have been detected are fragments of wood and other vegetable relics, and

Norfolk. (Mr. Lamplugh.)

these occur so abundantly, unmixed with other remains, in certain thin clayey seams intercalated with the sands, as to suggest that the deposit has accumulated under estuarine conditions; and this inference is strengthened by the general character of the sands.

From the Snettisham Beds a large number of marine fossils was obtained, chiefly in the form of sharp casts in the nodules of ferruginous claystone, which occur in the clays of the pits at Heacham, Lodge Hill, and Snettisham; and our knowledge of the fauna of this horizon has thereby been considerably enlarged. These fossils have been examined in the Palæontological Department of the Survey, and full lists of them are given in the Memoir on Sheet 69 just referred to. They include two species of *Crioceras*, *Belemnites* sp., *Pecten orbicularis*, *Pecten cinctus*, *Pholadomya Martini*, *Thetis Sowerbyi*, *Cardium subhillanum*, *Trigonia scapha*, and many other lamellibranchs, together with several gasteropods and other forms. Associated with these at Lodge Hill and Snettisham, numerous fragments of fern leaves were found, most of which appear to be referable to a Wealden species, *Weichselia* (*Lonchopteris*) *Mantelli*. In the ferruginous band which replaces the lower part of the clay south of Dersingham, the fossil-casts are rarely sufficiently well preserved for identification, but so far as could be determined the fauna seemed similar to that of the clay. The nearest equivalent to this fauna is found in the Tealby Limestone of Lincolnshire, and in the corresponding portion of the zone of *Belemnites brunsvicensis* in the Speeton Clay of Yorkshire.

The Carstone of Norfolk has yielded fossils only in a phosphatic nodular band near its base, where *Ammonites Deshayesii*, *Amm. cornuelianus*, *Perna Mulleti* and other characteristic "Lower Greensand" forms have been obtained by MR. W. KEEPING and others. This fauna has usually been considered derivative, but a re-examination of the fossils, and of the bed from which they were obtained, leads to the conviction that the fauna is on its proper horizon. It is not mixed, but is consistent throughout, and is newer than that of the Snettisham Beds. Its equivalent in the South of England will be found either in the lower part of the Hythe Beds or in the upper part of the Atherfield Clay, an horizon which, as stated in the *Summary of Progress* for 1897, is almost unfossiliferous at Speeton.

There appears to have been no break in the sequence of marine conditions from the time of the deposition of the Carstone to that of the Red Chalk in Norfolk, and the Carstone must therefore cover the interval represented in the South of England by the combined Hythe, Sandgate, and Folkestone Beds. The high polish which characterises the coarser sand-grains in the Carstone probably indicates their prolonged trituration on the bed of a shallow sea through the action of currents of medium velocity, in an area receiving accessions of sedimentary material at a very slow rate. The Spilsby Sandstone of Lincolnshire possesses in this respect similar lithological characters, and in both instances the lapse of time covered by the deposit, as

indicated by the changes of fauna, is very great in proportion to the thickness of the bed. Sandstones are probably, for the most part, rocks of rapid accumulation, but those of the type above described (which are not confined to the Lower Cretaceous rocks) evidently form exceptions to the general rule. In the Secondary rocks such sandstones are frequently associated with dark phosphatic nodules, which again are indicative of areas of slow deposition. Norfolk. (Mr. Lamplugh.)

To sum up the history of the Lower Cretaceous Series of Norfolk, we regard the Sandringham Sands as, in part or wholly, of estuarine origin, and presumably, for reasons fully discussed in the Memoir on Sheet 69, equivalent to some portion of the Tealby Clay of Lincolnshire. The Snettisham Beds, with their strongly localized and incomplete fauna, intermixed with macerated vegetable remains which increase in quantity southward, indicate the proximity of land and perhaps the presence in this area of a quiet inlet receiving land-drainage. They have been deposited at about the period of the formation of the Tealby Limestone and "Roach" of Lincolnshire. And the Carstone, like that of Lincolnshire, represents a shallow open sea which ushered in the period of gradual and widespread depression during which the Upper Cretaceous System in England was accumulated.

In the preparation of his monograph on the Upper Cretaceous formations of England Mr. Jukes-Browne has had occasion to consider with great care the accepted nomenclature of the various subdivisions of the rocks. He has found it necessary to introduce a new name for the Gault and Upper Greensand formations. He does not propose to abandon the use of these familiar names, but to retain them for the argillaceous and arenaceous deposits which have received separate colours on the maps of the Geological Survey. Their union, however, under one name is intended to show that they are not regarded as divisions of independent chronological importance. The name proposed is *Selbornian*, taken from the village of Selborne in Hampshire, which is so well-known from the descriptive letters of Gilbert White. Near Selborne the Malmstone attains its greatest thickness, being no less than 180 feet thick, while the underlying "Gault" marls and clays are about 100 feet, so that the whole has a thickness of 280 feet. Cretaceous nomenclature. (Mr. A. J. Jukes-Browne.)

The Selbornian stage will include the Red Chalk of Norfolk, Lincolnshire and Yorkshire, as well as the Gault, Malmstone and Upper Greensand of more southern counties. Where fully developed it is divisible into four palæontological divisions or zones, which in descending order are—(1) that usually known as the zone of *Pecten asper*, which, however would be more conveniently called that of *Holaster fossarius*; (2) the zone of *Ammonites rostratus* with its local sub-zone of *A. varicosus*; (3) the zone characterised by *Ammonites lautus*, *A. denarius* and *A. interruptus*; (4) the zone of *Ammonites mammillatus*.

A consideration of the facts connected with the occurrence of *Ammonites mammillatus* in England and France has led Mr. Jukes-Browne to attach the sands which contain this Ammonite

retaceous omencla- ture. (Mr. . J. Jukes- rown.)

to the Gault rather than to the Folkestone Beds. The zone of *mammillatus* is of small thickness in England, but over a large area of France it is from 20 to 30 feet thick, and moreover in this country this species ranges up into and is not uncommon in the clays of the *A. interruptus* zone.

TERTIARY.

The areas in which rocks of Tertiary age have been mapped last year by the Geological Survey lie in the south of England and the west of Scotland.

Hampshire.

Mr. Clement eid.)

MR. CLEMENT REID, who is charged with the revision of the Hampshire Basin, was engaged in the completion of various maps and Sheet-memoirs connected with that region. This indoor work has included the preparation of the following maps for publication:—Sheets 315 (Southampton) and 316 (Fareham), which were unfinished at the time of MR. WHITAKER'S retirement and the withdrawal of MR. HAWKINS to the office. The necessary field-work for the completion of these two sheets has been finished by MR. REID, and the maps will be sent to the engraver during the present winter; Sheet 328 (Dorchester) has been finally corrected and published.

Two short Memoirs, on Sheets 329 (Bournemouth) and 334 (Eastbourne), have been written and published during the past year. Another Memoir, on Sheet 328 (Dorchester), is well advanced and will be completed this winter.

A special Memoir, on the Water Supply of Sussex, prepared by MR. REID in conjunction with MR. WHITAKER, relates to a large extent to the Hampshire Basin. It is now in proof, and will be published early in the present year.

The present indoor work here noticed has taken so much time that it has been impossible for MR. REID to make much progress with the general Memoir on the Hampshire Basin. It is believed, however, that this year will see the completion of all the field-work of the district, only the Ringwood area being now left. It may also be possible to finish within the same time Explanatory Memoirs to all the Sheets of the map that are complete.

The past season's work has not yielded any striking scientific results, for the area examined is nearly surrounded by districts mapped in previous years and mentioned in former Reports. Considerable doubt exists as to the exact correlation of many of the Eocene strata, which rapidly vary both in lithological character and in thickness, and seldom yield any fossils. The mapping is thus necessarily lithological, and for the present the question must remain uncertain whether the Bagshot pebble-beds of the Botley district really represent the freshwater Lower Bagshot series of the Isle of Wight, and whether the similar pebble-beds lower in the series truly belong to the Reading Beds, or represent the basement-bed of the London Clay.

Dorset.

While engaged in mapping the Cretaceous formations of southern Dorset, MR. HINXMAN came upon a small patch of sand and gravel, presumably of Bagshot age, on the down between Compton Valence and Winterborne Abbas. A pit-section of these deposits shows 8–10 feet of rolled flint-gravel with many pebbles of vein-quartz, and white and grey quartzite. The gravel is interstratified with, and passes down into, yellow and orange gritty sand. Small deposits of a similar character have been mapped south of Frampton, and on the hill between Maiden Newton and Sydling St. Nicholas. (Mr. Hinxman).

Norfolk.

Some additional particulars have been obtained by MR. REID regarding the Pliocene and Pleistocene deposits of the Norfolk coast. A new well for the supply of water to Mundesley has furnished a section of Pleistocene, Pliocene, and Cretaceous strata, which corresponds with and supplements the section displayed in the coast-cliffs. The principal points of interest are the occurrence of loams with Arctic plants at the base of the Glacial deposits, and resting on quartzite-gravels belonging to the Cromer Forest-bed; the tracing of Weybourn Crag with the characteristic *Tellina balthica*, down to the Chalk at about 20 feet below Ordnance datum; and the discovery of soft greyish sandy Chalk of the peculiar Trimingham type, and like that Chalk, full of *Ostrea larva*. The tracing of the Chalk beneath undisturbed Pliocene beds is especially important in face of the discovery that Boulder-clay passes beneath the Chalk at several points near Trimingham, and that the enormous disturbed mass, half a mile in length, there seen, may therefore be a transported block entirely detached from the solid rock. This well is not yet completed, but apparently yields a good supply of water. (Mr. Reid).

Another somewhat similar well has been successfully completed at North Walsham. It shows:—

	Feet
Glacial Gravels	48
Contorted Drift	26½
Glacial Sands (the fine dust-like sands of Mundesley Cliff)	22
Till	4
Forest-bed (quartzite-gravels and sand)	22
Chillesford Clay?	½
Crag with shells	18
Chalk	109
	250

The Crag is apparently Chillesford or Norwich Crag, though the mollusca are too few to decide the question. *Tellina balthica* is not among them.

A third Eastern County well is of sufficient interest to be mentioned, as showing an exceptional thickness of Upper Pliocene. At Messrs. Youngman and Preston's Brewery at Lowestoft, situated at

(Mr. Reid.) the foot of the old cliff, a boring has been carried about 180 feet below the sea-level without piercing the Crag, the lowest beds reached being apparently Norwich Crag. This rapid thickening of the Pliocene beds, when traced towards the North Sea, corresponds with what occurs in Holland, and the occurrence of nothing but shoal-water fossils at all depths on both sides seems to support the idea that the present North Sea is largely the result of Pliocene or Pleistocene depression—a view that will explain also the discovery of numerous remains of Pleistocene land-mammals on the Dogger Bank, in the middle of the North Sea.

Scotland.

In Scotland the rocks that can be assigned to a Tertiary age consist almost entirely of volcanic and plutonic masses, which are chiefly developed on the west side of the country, and more particularly among the Inner Hebrides and in the basin of the Clyde. During last year MR. HARKER has continued his survey of the Cuillin Hills, in Skye, where he has mapped an exceedingly rugged group of mountains in greater detail than has ever been before attempted among the igneous rocks of this country. MR. GUNN, in the northern half of Arran, has made further progress with the survey of the interesting plutonic masses, which are now regarded as of Tertiary age. In other parts of the West Highlands more or less interesting examples of the Tertiary igneous series have been encountered.

Igneous Rocks of Skye.

(Mr. Harker.) With regard to his recent field-work in Skye, MR. HARKER has furnished the following report:—

Basaltic lavas with intruded sills.—The further progress of mapping on the basaltic plateaux to the north and west of Sligachan, of which some twenty square miles have been completed during the past season, shows that the rocks do not differ in general characters from the description given in the *Summary of Progress* for 1897. Intrusive sills continue to play an important part in the structure of the ground, and indeed it is noticeable that they become thicker and more conspicuous as we pass northward and westward from Sligachan, *i.e.*, away from the mountain district. Their source is evidently quite distinct from that of the great plutonic intrusions The sills attain their fullest development in what are now (in consequence of the superior durability of the sill-rocks) the highest parts of the plateau district, and here they usually surpass the lavas themselves in thickness. For instance, in a section through Monadh Meadale and Beinn Totaig, twenty sills have an aggregate thickness of 1,200 feet in a total of 2,000 feet. As elsewhere, two, three, or four sills often come together without any intervening lavas.

The rocks composing the sills are not all of one type, but are commonly either basalts or diabases. On the summit of Roineval, and at other places farther north, are thick sills of a beautiful porphyritic dolerite, and with this is sometimes associated a trachyte with a remarkable fissile structure, thus forming composite sills. Dykes of both rocks occur in the district, and have probably been the feeders of the sills, but composite dykes of the two rocks together have been detected in one or two localities only. (Mr. Harke

Composite sills of granophyre and basalt, of the type common in the Lias of the Broadford district, are rare among the basaltic lavas, but one fine example is seen in Allt an t-Sithean, near Sligachan. A composite dyke of similar structure, *i.e.*, with granophyre flanked on each side by basalt and each rock containing *débris* of the other, occurs close at hand, and can be traced nearly to the sill, of which it has presumably been the feeder. Sills of a similar basalt (with porphyritic felspars and corroded quartz grains) occur at one or two places close to the granite of Glamaig, and also entangled in the granite both on that hill and on the shoulder of the neighbouring Druim na Ruaige. The relations are probably the same essentially as in the symmetrical composite sills already referred to, but here the greater volume of the acid rock-magma has in great part destroyed the basic rock. For a considerable distance the granite is crowded with little round patches and spots of half-digested basalt.

The peculiar basic sills just mentioned are to be referred to an epoch very slightly anterior to the intrusion of the granite, but the ordinary basic sills, so abundant among the basaltic lavas of this district, must be younger than any of the great plutonic intrusions. This appears from the fact that the sills die out on approaching the tough, splintery, metamorphosed lavas which border both gabbro and granite, and are wholly wanting among the considerable patches of basalt lavas which are enveloped by those plutonic rocks.

The north-western border of the Cuillin Hills has been mapped as far as the mouth of Coir' a' Ghreadaidh. The junction here is an irregular one, the gabbro sending tongues into the basaltic lavas and enclosing portions of those rocks. No prolongation of the acid volcanic group of Bruach na Frithe has been detected, except a few relics of banded rhyolite and tuff entangled in the gabbro on the slopes of Sgùrr Thuilm.

The bedded basalts have also been mapped along the southern border of the mountains as far west as Garsbheinn, with the exception of a short length of coast-line at the head of Loch Scavaig, where the gabbro of the Cuillins comes down below sea-level. As elsewhere, the basalts clearly underlie the gabbro. There is no great thickness of them at this place, for the Torridon Sandstone soon emerges from beneath them on the western side of the bay, and the Lias on the eastern side. Tongues and veins of granite often occur in the lavas or along their junction with the gabbro above or the stratified rocks below, and on the shore west of Camasunary the granite makes a

r.) considerable strip. It is probably to this rock rather than to t the gabbro that the highly metamorphosed state of much of t the basaltic lava is to be ascribed. The rock is a white hornblend de- granite of the type found on the eastern side of the Blaven rang ge, and differs in some respects from the yellower granite of the Re Red Hills. In particular, it has much less tendency to th the 'granophyric' structure. It is often crowded with enclose osed fragments, in some places of Lias shales, in others of basalt.

Gabbro of the Cuillins, with intruded basic sheets.—Abo out twelve square miles of the mountains have been mappe ped during the year, including the north-western part of the grou oup and the basin of Coruisk. As before, the structure of the groun und was found to be extremely intricate, the complexity arising fro om three causes—(*a*) the frequent inclusion of patches of the basalti ltic lavas and agglomerates in the gabbro, especially near the margi gin of the area; (*b*) the composite nature of the gabbro mass itself elf, which is built up of many intrusions traversing and interlacing ing with one another; and (*c*) the multiplicity of later basi sic intrusions in the forms of dykes and sheets which intersect the he gabbro.

Most of the enclosed patches that have been mapped are of of the volcanic agglomerates, but this may be due in part to the he fact that these are more easily detected than the highly ly metamorphosed patches of basalt. In places, however, the he agglomerate also is so much altered as to become very obscure re, the finely divided matrix entirely losing its character. It seems ms probable indeed that the xenoliths of gabbro and basalt enclosed ed in the gabbro in many parts of the Cuillins are derived in some ne cases from the destruction of enveloped portions of volcanic ic agglomerate rather than from solid masses of gabbro and basalt, lt, although this certainly cannot be the source of the xenoliths in n all cases.

Although abrupt junctions of different kinds of gabbro, *e.g.* of coarser and finer-textured types, constantly attest the complex structure of the great gabbro mass, it has not been found practicable to take account of this in the mapping of the area. One type only is so distinct in appearance from the rest as to be easily followed by eye even at a distance, and has been mapped as an indication of the fashion in which the several component intrusions of the great laccolitic mass intersect and interlace with one another. This rock is conspicuous by the orange-red colour which it assumes on an exposed face, and is further characterised by an extremely rough surface due to little pits. These pits mark the position of xenoliths of a less durable type of gabbro, with which this peculiar rock is often crowded. It is confined to the western part or main range of the Cuillins, where it occurs sometimes in considerable bodies, sometimes in the form of dykes traversing the more normal gabbro, and in visible connection in certain cases with the larger bodies. On the other hand the same or a closely similar rock is found in the neighbourhood of the Mad Water (Allt a' Chaoich) entangled in, and veined by, a coarse-grained gabbro of normal type.

Like the area already reported on, the gabbro tract surveyed during the past year is remarkable for the great profusion of minor intrusions of basalt and diabase which traverse it in the form of a series of parallel sheets. The dip of these sheets follows the rule already pointed out, being always towards the centre of the whole gabbro area. Thus at the head of the Coruisk valley and on the neighbouring mountains the dip is E., around Loch Coruisk N.E., on Sgùrr na Stri N., and on Blaven N.W. As before, these basic sheets are found to cease abruptly at or near the outer edge of the gabbro area, nor do they enter the granite of Marsco, Druim an Eidhne, etc., which in part breaks through the gabbro. Further, there are tracts in the gabbro itself where the sheets are almost wanting. This is the case along the Sligachan River, on Druim an Eidhne, and on the shores of Loch na Crèitheach and Loch Coruisk; all places where the base of the great gabbro laccolite is not far beneath the surface. At the base of the gabbro, as seen along the *outer* boundary of the area, the sheets are abundant, and they occur in the granite which is exposed along the outer (eastern) base of the Blaven range. (Mr. Harke

Dykes intersecting the basaltic lavas and gabbro.—Basic dykes continue to be met with in great profusion both in the basalt and in the gabbro area. Where the rocks are well exposed, the field-maps often show as many as a hundred dykes in a square mile, presenting a remarkable contrast to the granitic tract, where an equal area contains on an average only five or six dykes at most. The distribution of the dykes is, however, not uniform either on the basalt plateaux or on the gabbro mountains. The comparative fewness of dykes on some of the higher moors is doubtless to be ascribed to the difficulty they experienced in penetrating the massive sills of which these elevated plateaux are mainly built. There are also places relatively free from dykes within the gabbro area, and this, too, is probably not without significance. Thus the basic dykes are almost wholly wanting between Loch a' Choire Riabhaich*, and the mouth of Harta Corrie. This may plausibly be explained by the protection afforded by the underlying granite, which is seen on Druim an Eidhne passing under the gabbro. Farther north, in the Sligachan valley, where the contact of gabbro and granite is vertical, the usual dykes occur in the former rock up to the junction. Again, the granite of Ruadh Stac and Loch an Athain undoubtedly extends for some distance eastward beneath the gabbro of the Blaven range; and accordingly we find dykes far less numerous on the western than on the eastern slopes of that range. Another part of the gabbro area in which dykes are few is that between Loch Scavaig and Coire an Uaigneis, along the south-western side of the Coruisk valley. We have no certain evidence of the existence of subterranean granite here, but it is possible that the granite seen rising above sea-level on the shores

* The southerly tarn of this name, near Loch Coruisk, not the one near Sgùrr nan Gillean.

Mr. Harker.) of Loch Scavaig is prolonged in this direction: indeed dykes and veins resembling the known apophyses of the granite are found. The mapping during the past season has given additional confirmation of the fact that the fewness of dykes in the granite does not imply the posteriority of that rock to the majority of dykes in the district, but is due to the resistance which it opposed to their passage. The *smaller* bodies of granite and the offshoots from the larger masses are as freely traversed as the neighbouring gabbro and basalt. Another rock which is commonly poor in dykes is the volcanic agglomerate, and we even find basalt dykes which traverse the gabbro stopping abruptly at the junction of an enclosed patch of agglomerate. Petrographically, the basic dykes present a variety of types—diabases, dolerites, and basalts—mostly without any special peculiarities. Olivine conspicuous to the eye is not often seen, excepting in a group of porphyritic olivine-basalts (specific gravity 2·86—2·89) restricted to the granite area.

Dykes of other than basic composition make up but a small proportion of the whole. The trachyte dykes already mentioned are, however, well represented in some parts of the basalt area, especially in the neighbourhood of Drynoch. Like the basic dykes, they follow a very general N.N.W.—S.S.E. direction. The rock composing them is fine-textured and without conspicuous porphyritic crystals. It has a specific gravity 2·64, and consists almost wholly of slender prisms of felspar, both orthoclase and oligoclase, with a fluxional arrangement, rare flakes of biotite being the only other constituent. It resembles generally a rock previously noted, which occurs in numerous dykes in the Broadford district; but it has less of the potash and more of the soda-bearing felspar. The Broadford dykes give specific gravities of 2·50 to 2·55.

True acid dykes are more uncommon on the basalt-plateaux, and they are rarely met with in the part of the gabbro area surveyed during the past year. The most interesting group is that which traverses the gabbro and volcanic agglomerates and tuffs of Druim an Eidhne (Drum-hain), and is characterised by a beautiful spherulitic structure and fluxion-lamination. Some of the spherulites are from an inch to two inches in diameter, with a complex plumose structure. These dykes are near the fine-textured and often spherulitic margin of the granite, and many of them can be traced into continuity with it.

Isle of Arran.

Mr. Gunn.) Of the well-known granite of Arran which forms the picturesque mountain-group in the northern half of the island, the greater part has been surveyed by MR. GUNN. He has now completely traced its boundary-line with the surrounding rocks. Some of the finest junctions of the granite with the schists, which show the intrusive character of the igneous rock in North Glen

Sannox were described more than a century ago by HUTTON,* and have since been often referred to, but other junctions quite as striking occur on the east side of Glen Catacol at Madadh Lounie and in several places north of Meall nan Damh. The granite maintains generally its ordinary coarse character near its junction with the schists, but there are several places where it is fine-grained at the margin. (Mr. Gunn.)

Several writers have described a finer-grained granite in the interior, without attempting to define its exact boundaries. It is intrusive in the coarser variety which surrounds it, and is therefore of somewhat later date, but both evidently belong to one great period of plutonic action, as they have generally the same sets of joints, and they are alike penetrated by all the varieties of dykes (quartz-porphyry, felsite, pitchstone, basalt, &c.). The finer kind of granite occupies nearly all the west side of the Iorsa Valley, so that on this side the coarser variety is but a comparatively narrow strip, varying from one mile in width to not more than a furlong at Iorsa Loch. On the east of the Iorsa Valley most of the granite is of the coarser kind, and the boundary between it and the fine (part of which was mapped by the present DIRECTOR GENERAL in 1872) is tortuous, some bays of the fine being almost detached and surrounded by the coarse. All the peaky hills are formed of the coarse kind, the finer variety forming rounded or flat-topped hills, generally of lower elevation. Usually the fine variety breaks up into small slabs, which often so entirely cover the surface of the ground that no solid rock is observable. The débris of this rock is nearly white in colour. Occasionally, however, the finer granite becomes coarse, and then breaks up into larger blocks, and forms crags. Good junctions of the two granites are to be seen on the south side of Beinn Bharrain, on Sail Chalmadale, and in Glen Easan Biorach.

In addition to the main mass of finer granite, numerous small dykes and sheets of it have been intruded into the coarse in various places; but most of these are not large enough to be separately mapped. Sometimes, however, larger intrusions of this character are met with. In one of these, near the head of Glen Sannox, on the south side of Caisteal Abhail, where the rock has a markedly jointed structure, a closely laminated band of fine granite about nine feet in width may be traced for a hundred yards or more. This is a peculiar rock, and differs from the fine granite which surrounds it in having an approach to a linear arrangement of the quartz in the rock. It weathers into very thin plates or slabs, and looks at first sight more like a schist than a granite. It, however, has its laminæ dipping steeply to the west, exactly in the same way as the joints do in the adjoining fine granite.

The majority of the igneous dykes in the island of Arran are newer than the granite, but a few are certainly of older date.

* In the unpublished third volume of his Theory of the Earth, of the MS. of which a surviving portion is about to be given to the world by the Geological Society. Hutton's observations were made in the year 1787.

(Mr. Gunn.) One of these has already been described from the Cnocan Burn dam south of Goatfell, and another was met with this year at Creag nan Gobhar on the west side of Glen Catacol. In the latter case veins of granite penetrate the dyke, which has been changed from a basalt to a diorite.

Dykes of various kinds seem to be nearly as numerous in the granite as in any of the other rocks of the island. Many basalt dykes may be seen along the west shore from Machrie Bay northward, and along the northern part of the island, but few of them can be identified with those met with in the interior. Many are small and their courses irregular. The largest occurs between Imachar and Balliekine, and is in places 100 feet in width.

Dykes of various kinds have been traced for long distances in the granites, and one in particular, a quartz felsite, which follows a north and south course over Beinn Tarsuinn and the south-east of Beinn Nuis, can be followed for more than two miles. On Beinn Tarsuinn it seems to be quite 40 yards wide, but it divides into several branches striking to the north. To the south-east of Beinn Nuis its width is 75 feet.

To the north of Caisteal Abhail a remarkable dyke of porphyritic pitchstone of a dark green colour, and which is beautifully columnar, may be traced for many yards by the columns which lie about on the surface, and vary somewhat in form as well as in size. None of the rock, however, is actually seen here *in situ*.

Argyllshire.

Between the vast basalt plateaux of the Inner Hebrides and the complex protrusions of Arran many less conspicuous illustrations of the Tertiary volcanic activity may be observed. During the past year some volcanic necks have been met with in the west of Argyllshire, which, though their age cannot be definitely fixed, are not improbably referable to the Tertiary period. They belong to the same class as those formerly described from western Ross-shire and Raasay.

District of Loch Eil. (Mr. Grant-Wilson.) One or two of these hitherto unobserved vents have been detected by MR. GRANT-WILSON among the hills on the north side of Loch Eil, where they pierce the prevalent quartzose flagstones of that part of the Highlands. The largest of them forms a curiously knobby summit to the mountain known as Stob a Ghrianain (Sunny Point, 2,420 feet). The hill top being free from drift, the form of the orifice can be clearly made out. In ground-plan it is somewhat bow-shaped, with the curved side towards the south-east. Its extreme length is 730 yards, and its breadth 266 yards. At the north-west corner the more or less vertical wall of the vent is seen. The material that has filled up the orifice is an agglomerate, which is occasionally very coarse. In some parts it is mainly made up of fragments of the surrounding micaceous flagstones. Elsewhere it consists of an igneous matrix, enclosing fragments of flagstone, which are mostly

subangular. Some of these are wrapped round in a finer matrix of igneous material, but the chief rock is a decomposing basalt. The rounded flagstone fragments may have acquired their shape from attrition in the volcanic chimney during successive explosions. On being broken open they show an altered and baked outer surface surrounding a less altered core. One of these rounded fragments was examined by MR. TEALL, who reports regarding it:—"[8197] Quartz-biotite granulite. The optical characters of the biotite have been more or less destroyed. The mineral is turbid, feebly pleochroic, and without the strong characteristic double refraction." District of Loch Eil. (Mr. Grant Wilson.)

One of the largest blocks of flagstone measures 15 feet × 12 feet × 5 feet. It thus contains 900 cubic feet, and must weigh about 70 tons. This block is clearly seen to have been traversed by a granite dyke prior to its being broken off from its parent source, so that the volcanic episode belongs to a far later period than that of the granite intrusions. In the matrix of the agglomerate, augite, olivine, volcanic glass, and mica are common, while the bulk of the magma that was disrupted by explosions seems to have been composed of basalt. A specimen of this basalt was submitted to MR. TEALL for examination, who remarks regarding it:—"[8198] Compact black basalt, containing numerous small fragments of biotite-granulite, and probably also detached mineral grains derived from the granulite. The basalt itself is composed of serpentinous pseudomorphs, in part at least after olivine, and a ground-mass of microlitic augite, magnetite-dust, biotite, and a colourless apparently isotropic base. The true character of the ground-mass can only be seen in very thin sections with a high power. No felspar undoubtedly belonging to the basalt has been detected. The rock has the structure of the nepheline- or analcime-basalts, and is probably referable to this group."

This neck, as it now exists, is clearly a portion of the original volcanic chimney, any overlying and surrounding cone of detritus which existed having been removed by subsequent denudation. Another small "neck," about 50 yards in diameter, is seen in the channel of a rivulet 700 yards to the south-west of the Stob Ghrianain. A third vent lies 250 yards to the S.E. of the 2,385 feet cairn on the Druim Fada. It is oval in shape, 80 yards long, and stands up prominently above the surrounding flagstones. It is almost entirely composed of small pieces of flagstone and quartzite embedded in a fine-grained ashy matrix.

Nearly forty miles to the south of the group of vents above Loch Eil, MR. SYMES has come upon another neck on the moorland between Loch Feochan and Loch Scamadale, about six miles south from Oban. This example presents a number of peculiarities. In the first place, it rises amidst the lavas of Lorne, so that it must be of later date than some part of the Lower Old Red Sandstone. In the second place, it is filled up with acid and not basic material; and lastly, it appears to be connected with some of the younger (presumably Tertiary) dykes, so that in this way it supplies more definite information as to its probable age. Lorne. (Mr. Syme

This neck is pear-shaped in plan, narrow at the north end and
nes.) widening southward, its maximum length being about 120 feet. It is filled with a coarse agglomerate, some of the blocks in which measure two or three feet in diameter. The fragments consist largely of a remarkable greenish rhyolitic rock with exquisitely developed flow-structure, but they also include pieces of the surrounding andesitic lavas, of the pink biotite-andesite, which occurs in dykes and sills in the Lorne volcanic plateau, and of some basic rocks like the material of many of the Tertiary dykes. While the neck pierces the andesitic lavas and their associated porphyry dykes, it appears also to truncate one of the numerous rhyolite dykes of this district, to which reference will presently be made. Immediately to the south of it, a broad dyke of rhyolite or trachyte appears, exactly similar to the peculiar rock of which the blocks in the neck so largely consist. This dyke is one of the composite kind so abundant in Skye, for it is flanked on either side by a narrow basic dyke. A little further south, in the ravines of the Eas Ruadh, which descends into Loch Scamadale, similar rhyolites or trachytes pierce the andesitic lavas, and are again accompanied by marginal bands of basalt. In one example the acid rock may be seen to enclose a portion of a dyke so highly basic as almost to become a peridotite. These rocks are obviously of far younger date than the age of the Lower Old Red Sandstone. The peculiar characters of the acid material and its association in compound dykes with basic walls seem to link these rocks with the Tertiary volcanic series of the west of Scotland. If this be established as their true geological horizon, they furnish fresh evidence of the wide extent and variety of the phenomena of dyke-intrusion during older Tertiary time.

A specimen from one of these acid dykes was sliced and submitted to MR. HARKER for petrographical determination, and he has supplied the following note respecting it:—

"A dull white compact-looking rock with a few little glistening specks, which are crystals of quartz and felspar. The slice shows scattered porphyritic crystals, usually less than $\frac{1}{10}$ inch, of quartz in good pyramidal crystals, and felspars (albite and sanidine) sometimes intergrown in micro-perthite fashion. The ground-mass is essentially of felspar and quartz, the latter evidently in great part of secondary origin. The felspar is in bunches of little prisms, but the original structure of the rock is much obscured. It seems to belong rather to the rhyolitic than to the trachytic family. The secondary quartz of the ground-mass might be derived from the rock itself, or from an extraneous source, but the porphyritic quartz seems to mark the rock rather as one of acid composition, since the felspars are doubtless all alkali-felspars. Leaving out of account rocks of the dacite family (which is not in question here), porphyritic quartz crystals may be taken as characteristic of rhyolitic rocks of intrusive type; in the rhyolitic lavas they are often wanting."

At great distances from the main centres of Tertiary volcanic activity, basic dykes having a prevalent north-westerly trend continue to be abundant in the ground most recently surveyed in the west of Scotland. They are subject to local augmentations of number, and in some places become so plentiful and lie so close together that it is difficult, or impossible, to represent them all,

even on maps on the scale of six inches to a mile. As the survey has advanced south from Oban, one of these tracts of prolific dyke-intrusion has been entered. Admirable sections are laid bare along the coast-line, where the dykes may be studied both in ground plan and in vertical section. (Director General.)

Some instructive sections may be here referred to which are visible along the shores of the island of Seil, to the north of Easdale. The prevalent rock of the island is the black slate which has so long been quarried here and on the opposite island of Easdale. These slates are traversed by numerous dolerite dykes, which occasionally throw off tortuous interlacing veins. It is interesting to note that where the basic rock assumes these ribbon-like or filamentous forms, it has undergone the characteristic decomposition into "white trap," which is so generally observable where basic material has been injected into rocks of a more or less carbonaceous composition. The proportion of carbon in these black slates must be small, but it has been sufficient to superinduce this peculiar type of alteration.

One of the most striking sections on this coast is furnished by a compound dyke which cuts the slates on the beach about a furlong south-east from the schoolhouse. This intrusion is made up of at least ten bands of dolerite, which, though in a general sense parallel to each other, occasionally diminish in thickness, bend in their course, and thus allow wedges of the surrounding slates to come in between them. Where no such foreign intrusions appear, the whole igneous mass might at first be taken for a single broad dyke, but a little examination discloses that its individual bands are in several cases separated from each other by a selvage of black glass, which is sometimes two inches thick, but dwindles down to a mere film or glaze on the wall of the dyke. The dolerite assumes an exceedingly coarse grain for several inches before it is succeeded by the vitreous layer. Here and there strips of glass lie within the body of a dyke some way back from the wall, without any evidence that they there mark outer margins of distinct dykes. One of the dykes presents a number of cavities, some of them three or four inches in diameter, which are lined with small pea-like spherules of the same black glass. Mr. Symes has found that many of the dykes have a spherulitic structure at their outer margins, the spherules being grouped in rows like those observed by Mr. Clough in Skye, and that these rows or chains are sometimes inclined to the horizon at an angle of 10° to the S.E. (as at Gallanach to the south of Oban), as if the molten magma had ascended in the fissure from a south-easterly direction.

In the district surveyed by Mr. Grant-Wilson both to the north and south of Loch Eil many dykes of presumably Tertiary age have been met with. Thus on the ridge of Druim Fada, already referred to for its volcanic necks, a group occurs of which the largest is not more than four feet broad. On the west side of Glen Albyn they are more numerous; several cut the diorite of Dykes in th Loch Eil district. (M Grant-Wilson.)

Dykes in the Loch Eil district. (Mr. Grant-Wilson.)

Glen Loy and exhibit chilled edges. A specimen from one of these examined by MR. TEALL is thus described by him:—

"[8289.] Basalt.—Under the microscope a few microlites of felspar and pseudomorphs after skeleton crystals of olivine are seen in a deep brown matrix which shows some action on polarised light, but which must originally have been a tachylite. There are a few minute black grains (magnetite), but most of the iron was obviously retained in the glass. The basalt shows a slight banding parallel with the junction."

Several basalt dykes are also exposed in the stream draining the Monadh Beag. Close to the second milestone on the road leading from the Corran to Conaglen, two dolerite dykes cut the granite. Examined under the microscope by MR. TEALL, one of these specimens [8200] was seen to be "composed of phenocrysts of basic plagioclase and augite, both occurring in crystalline groups in a ground-mass of lath-shaped plagioclase, augite, and iron-ores. Carbonates are also present in the ground-mass. It is a dolerite." A similar dyke is seen cutting the flagstones in the old quarry to the south of Muirshirlich poor-house.

PLEISTOCENE, INCLUDING GLACIAL.

So many interesting and important questions regarding the latest phases in the geological history of the British Isles depend for their solution upon a detailed study of the superficial deposits that steps have recently been taken to methodise more definitely than hitherto the systematic investigation of these deposits by the Geological Survey. In particular it seemed desirable to secure greater precision and uniformity in the noting and collecting of such organic remains as occur in the accumulations in question. The peat-mosses for example, which cover such large tracts in many parts of these islands, have never yet been systematically explored, with the view of ascertaining what evidence they and their associated sediments may yield as to former differences of climate. Accordingly some suggestions have been drawn up by MR. CLEMENT REID, who has devoted special attention to the subject. These have been circulated among the staff of the Survey for the information and guidance of the officers engaged in mapping the superficial deposits. As, however, they possess a general interest, and may be useful outside the ranks of the Survey, they are here inserted.

Mr. Reid on the investigation of some recent deposits.

The Post-glacial climatic changes that have occurred in Britain need more thorough investigation. The succession of cold and warm, or wet and dry, periods represented by the deposits above the Boulder Clay can be decided by an examination of the contents of the ancient peat-mosses and similar strata. It is necessary for this purpose to collect evidence from various districts and from various heights above the sea level.

Four main questions still remain unanswered:—

1st. What caused the dying away of the glaciers and ice sheets? Was it merely an increase of temperature, or was it the commencement of a period of dry cold, like that indicated by the loess of Central Europe?

2nd. After the disappearance of the ice and the incoming of a Temperate flora was there a general recurrence of cold conditions (but not glaciation) and re-entry of Arctic plants? Or are the deposits with a Temperate fauna and flora in the southern half of England equivalent to deposits lying below moraines in regions further north? Mr. Reid on the investigation of some recent deposits.

3rd. What was the relation of Palæolithic man and of the Pleistocene mammals to these climatic changes? What is the meaning of the break between Palæolithic and Neolithic? What physical and climatic changes did Palæolithic and Neolithic man respectively see in this country?

4th. What was the maximum amount of local submergence or elevation in Post-glacial times, and to what extent were the different islands connected?

To answer these questions it is necessary systematically to examine the "submerged forests"; especially where in dock-excavations or such-like works several successive land-surfaces can be seen. Valuable results may be obtained by the study of sections through the deposits of silted-up lakes, especially when these lie in hollows in the Drift, and may therefore show a continuous series of strata from the passing-away of the ice to the present time. Peat-mosses also should be examined, and notes be taken of the size of any trees contained in them at considerable heights above the sea, especially of the former upward limit of the pine and oak.

In the collection of samples for further examination it should be borne in mind that unless the stratigraphical relations of the deposits are clear, it will scarcely be worth while to carry the material far or to undertake the slow work of pulling it to pieces and washing it. Among the samples needed, especially from the south-west of Ireland, are the bottom layers of a peat-moss, generally consisting of loamy or marly beds mixed with peat. These in England and Scotland often yield leaves of Arctic plants differing greatly from the Temperate flora of the overlying peat. Below the peat are sometimes found deposits of shell- or *Chara*-marl with *Megaceros*. These marls apparently yield relics of a flora less Arctic than that of the basal peat above; the fossils should therefore be kept separate, and a sample of the marl taken for washing for the smaller species.

If any Pleistocene mammal is found with the bones associated, it is desirable to save part of the matrix; for the climatic conditions under which certain of the larger mammals flourished is so little understood that we cannot at present point to their occurrence or non-occurrence as evidence of any change. Detached bones are of less importance, and may have been washed out of an older deposit.

A pound or two of carefully selected material properly examined will generally yield a clear indication of the origin of the deposit, the approximate climatic conditions, and whether the

Reid on nvesti- n of recent sits.

strata are likely to repay further examination As, however, it is important that time and labour should not be spent on the collection of valueless samples, it may be pointed out that the thorough study of a selected locality, where the succession is clear, is far more important than the collection of miscellaneous samples over wide areas where no succession can be obtained. The ordinary fibre or moss-peat of a large peat-bog is of little interest, as it generally yields only the common wide-spread marsh and aquatic species still living in the country. Deposits filling a small silted-up channel or lake are of far more interest, for besides aquatic forms they yield remains of various dry-soil animals and plants which have fallen or been blown in from the adjoining banks; they are also more sandy or loamy, and therefore more easy to examine, and they contain fossils in better preservation. Great care, however, is needed to avoid confusion through landslips, or creep of older deposits over the peat. The specimens collected should be obtained after careful removal of the exposed surface, so as to eliminate any recent seeds or leaves which may have fallen on it.

Calcareous tufa contains relics of many perishable species which cannot be preserved under other conditions. It also, more often than other deposits, yields well-preserved plant-remains, such as give the clearest evidence of climate. Tufas of older date than the Neolithic Period should be carefully examined, and search should be made for hard tufas in old valleys or channels hidden under Glacial Drift.

Examples of the kind of investigations needed may be seen in Mr. Strahan's work on the "submerged-forests" of the Barry Docks (*Quart. Journ. Geol. Soc.* Vol. LII., p. 474, 1896); Mr. Bennie's researches in the fauna and flora of the silted-up lakes in central Scotland (*Annual Reports of Geological Survey* for 1894, 1895, 1896); and the Report of the British Association Committee on the "Relation of Palæolithic Man to the Glacial Epoch," 1896.

In the following notice of the recent progress of the Survey among the Glacial and other Pleistocene deposits of the country, it will be most convenient to follow a geographical order, beginning with the southern and central counties of England, and then taking in succession Wales, Scotland, and Ireland.

mpshire. Reid.)

In the Hampshire basin Mr. Reid has encountered only a continuation of the same deposits which have been described in previous Reports. These have all been decalcified, and yield no fossils except Palæolithic implements.

rdshire. Blake.)

In Oxfordshire Mr. J. H. Blake has definitely mapped the boundaries of superficial deposits of which at most only the existence had been previously indicated on the maps. Thus between Waterstock and Great Haseley, a few miles to the east of Oxford, he has traced an irregular plateau of high-level or hill gravel which measures two miles in length from east to west, with a breadth of a mile and a quarter at the east end. This gravel overlies the Gault, and consists chiefly of flints, quartz, and abundant rounded pieces of quartzite. In the central parts

where the deposit is thickest, it has been proved by well-sections to be from 10 to 12 feet in thickness. The highest portion of its surface is about 337 feet above Ordnance Datum, and from 150 to 160 feet above the level of the river Thame to the northward and westward of it. This outlier, which occupies the highest ground in its vicinity, and is independent of the present drainage system, shows in a marked manner the large amount of denudation that has taken place since its deposition. Oxfordshir (Mr. Blak

In the areas north of the Charnwood Hills, and between the Trent and the Soar, which have been surveyed by Mr. Fox-Strangways, not much boulder-clay or gravel has been met with. Patches of these deposits occur on many of the hill-tops, but they are generally thin, and, as in the Oxfordshire example just referred to, have evidently suffered extensive denudation. There appears to be more drift in the valley of the Soar than in that of the Trent. The alluvium of these rivers is extensive, as within a short distance the four large Midland streams—the Dove, the Derwent, the Soar, and the Trent—unite their waters. This deposit consists mainly of gravel, with but little clay. What clay there is seems to have been washed into the lower districts, which are liable to floods at the present time. The ground is intersected by innumerable old river-courses, which are interesting in that they show how frequently the streams have changed their position in quite recent times, and how the main stream has frequently blocked and diverted a tributary branch. On either side of this great valley there are extensive gravel terraces, which are probably of late glacial age. Mr. Deeley* calls them "interglacial"; but Mr. Fox-Strangways has not as yet seen any evidence to lead him to suppose that glacial conditions were very marked after the deposition of these gravels. Leicestershire and Derbyshir (Mr. Fox-Strangways

North Staffordshire.

During the revision of the North Staffordshire coalfield advantage has been taken of the opportunity to map also all the superficial deposits, as these had not previously been surveyed. By the recent increase of the staff in this district some progress has been made with the Drift survey, and various facts of considerable importance in regard to the glaciation of the Midland Counties have been brought to light. The area assigned to Mr. Lamplugh has been examined by him between Uttoxeter and Leigh, and northwards to the villages of Upper Tean and Denstone, as well as eastwards to the valley of the Dove. The underlying formation of the greater part of this area is the Keuper Marl, which forms undulating ground that rises to somewhat over 500 feet above Ordnance Datum-level. On the north-west side a higher ridge of Keuper Sandstone and Bunter Pebble-beds reaches 739 feet in altitude. The Drift is spread scantily, in (Mr. Lamplugh.)

* *Quart. Journ. Geol. Soc.*, vol. xlii., p. 467.

Lamp- patches of limited extent, over the solid rocks, being most fully developed in small plateaux on the higher ridges, while the slopes and the minor valleys usually either contain none or exhibit, at the most, a pebbly soil overlying the Marl to a depth of one or two feet. The lower flanks of the broader valleys, however, frequently present disconnected banks and terraces of stony loam and pebbly gravel which are not connected with the present conditions of erosion in the country, and are probably of fluvio-glacial origin.

The prevalent Drift of the higher ground is a red sandy loam, or more rarely, clay, containing numerous rounded quartzite and other pebbles derived from the Bunter (which frequently show the characteristic pittings) together with an occasional partially rounded fragment of hard sandstone probably derived from the Carboniferous rocks. The absence from most of the district of stones larger than about one foot in diameter and of any showing clear proof of glacial striation, together with the sandy character and local derivation of the material, seem to render the term "boulder-clay" somewhat inapplicable to this deposit. Evidence was obtained, however, that in spite of its abnormal composition and general resemblance to "rain-wash," the material is the local equivalent of the true boulder-clay of contiguous tracts, and has had a similar derivation from the moving mass of land-ice by which the whole country has been covered. The clearest proof of this was furnished by the presence of well-glaciated surfaces of Lower Keuper Sandstone at an elevation of 700 feet above O.D. (almost the highest ground in the neighbourhood), which were uncovered towards the end of last year in the large quarries at Hollington. These surfaces were directly overlain by the usual pebbly loam of the district, of rather unusual thickness (from 10 to 25 feet), and the direction of the striæ—W. 20° N. to E. 20° S.—shows that the movement of the ice has not been determined by the shape of the ground in the vicinity nor by the presence of the elevated Carboniferous Limestone tract of the Weaver Hills a few miles to the northward, but has been consequent upon the pressure of the great ice-sheet which was piled up over the lower ground to the westward and north-westward. As this is the only locality in the district where there is any rock sufficiently coherent to exhibit such traces of glaciation, it is fortunate that the quarry-sections should afford such opportune exposures.

Further evidence that the pebbly loam must be regarded as a local variety of the boulder-clay of the great ice-sheet is afforded by the fact that on the rising ground south of Uttoxeter, opposite to the great bend in the Dove Valley, where the river swerves from a southerly to an easterly course, the pebbly loam is suddenly replaced by a true till in which large subangular striated boulders of Carboniferous Limestone, toadstone, and other rocks are abundant. This material evidently indicates the path taken by the stream of ice which has descended the valley of the Dove; and MR. LAMPLUGH urges that its local development in relation to the more prevalent type of pebbly drift tells

strongly in favour of the land-ice as opposed to the marine theory of the origin of these drifts. (Mr. Lamplugh.)

The absence from the greater part of the area examined of the large boulders of Lake District and other far-travelled rocks, which are so abundant in the country a few miles further to the westward and north-westward, is very noticeable, especially as the main ice-flow has been from that direction. It is probable that the lower layers of the western ice-sheet in which these boulders were mainly lodged were arrested by the steep Bunter escarpment, and that only the cleaner upper part of the mass, formed from the snowfall on the surface of the ice-sheet, moving as an upper current over the lower part, overrode this district. By this cause, also, we may explain the production of the drift-plateaux on the tops of the pre-existing ridges. These drifts seem to have been formed near the peripheral margin of the western ice-fields and close to their confluence with the eastern ice which brought the chalky drift into and across the main valley of the Trent above its junction with the Dove.

Immediately to the eastward of the Dove between Rocester and Uttoxeter, and also on the ridges due south of Uttoxeter, grey flints from the chalk occur rather plentifully in the glacial gravels, and are present in diminished numbers at lower levels in the gravels of similar age which extend westward from Uttoxeter to Bramshall, while scattered fragments of the same material were observed in the drift to the west and north of Stramshall two miles N.N.W. of Uttoxeter, but were not found farther to the northward or westward. The dispersal of these flints has probably been effected by the floods from the western margin of the eastern ice; and when the drifts of the country to the southward and eastward of the present area have been surveyed, it should be found possible to map out with considerable accuracy the limits of the ice-flows from the opposite sides of England.

In the higher reaches of the drainage-basin of the Dove, north of Ashbourne, the composition of the drift is totally different from that of the area above described, for it is made up almost entirely of extremely well-glaciated Carboniferous Limestone débris. These strongly-marked local variations in the character of the glacial deposits of contiguous districts not only negative the theory of the marine origin of the drifts of the Midlands, but also afford presumptive evidence that they have all been formed at about the same period, and by a single glaciation; and not, as sometimes supposed, by several periods of glaciation separated by mild intervals.

In the Keuper Marl district the glacial gravels are of some economic importance, since, being made up so largely of quartzite pebbles from the Bunter, they make useful road-metal and afford the only local supply of such material. The sands associated with the gravels are, similarly, the only local source of this substance for use in building. These gravels and sands are curiously sporadic in their distribution, occurring in small patches here and there on the highest ground, especially at the ends of

hilly ridges, as well as in irregular banks in the valleys. Hence a careful survey of the whole area is necessary in mapping them. Their composition and mode of occurrence show that they are part and parcel of the general drift of the country, representing, in fact, the material of the pebbly loam assorted by the action of running water.

Over the area of the North Staffordshire coal-field the drifts have been mapped by MR. GIBSON, while to the west of it these deposits have been surveyed by MR. WEDD. According to the latter observer, a line drawn from Madeley on the north-east to Market Drayton on the south-west roughly divides the district into a drift-covered area on the north-west side, and an almost driftless area on the south-east. The drift sweeps south-eastwards from the Cheshire plain for some distance up the flanks of the sandstone hills, and enters the valleys which open to the north-west. The same divisional line has been found by MR. GIBSON to continue north-eastward to near Audley, between drift-covered ground to the west and driftless or nearly driftless ground to the east. The driftless portion is triangular in shape, the apex lying towards Audley. The east and west sides of the triangle coincide with the lines of the Bullhurst Large Fault and Apedale Fault, while the interior forms the highest ground to the west of the Potteries. Round Pipegate the Trias comes close to the surface, or so close to it as to show the thinness of the drift thereabouts.

In the drift-covered area around Woore and Bellaport MR. WEDD finds a tumultuous assemblage of mounds and hillocks of sand or clay, of clay capped with sand, or of sand capped with clay. He believes that the majority of such hillocks, and especially when large or isolated, are in part or entirely composed of sand. About Pipegate, Woore, Madeley, and Betley large areas of continuous sand occur, while in other parts where sand is abundant it is found on the surface only in patches cropping out from under, or flanking, or capping hillocks, as in the neighbourhood of Bellaport. Two good examples of basins surrounded with drift-sand are to be seen in Betley Mere and Craddocks Moss, the former being a sheet of water lying in peat, and the latter a peat bog.

With the exception of small isolated patches of drift-sand and clay at Keele (575 above O.D.) and Acton, MR. GIBSON finds the area to the east of the divisional line as far as the Trent Valley almost, if not entirely, free of drift, except in the valleys. Drift-clay with many erratics is found in the valley of the Lyme, while both clay and sand appear in the Trent Valley around Stoke-on-Trent and Bucknall.

It is noticeable that large boulders are more numerous in areas where drift-sands and clay are feebly developed. A large number of specimens of these boulders has been collected with a view to such a careful examination of them as might indicate their sources of derivation, and thus throw light on the movements of the ice over the north and centre of England. This collection of samples from the boulders has been studied by MR HARKER, who is well acquainted with the rocks of the Lake

District and the northern counties. He finds that though there (Mr. Harker)
are many boulders as to the origin of which no definite opinion
can be expressed, a considerable number may be assigned with
certainty, or with varying degrees of probability, to the Lake
District of Cumberland. These include:—Eskdale granite in
its various phases, distributed uniformly over the region;
Buttermere granophyre, boulders of which are also widely and
generally distributed; a rock with acicular crystals of augite
closely resembling a certain local modification of the Carrock
rock, common in the Hanchurch, Whitmore, and Willoughbridge
districts; with less confidence, a rock very like parts of the
Skiddaw granite, and another containing garnets which recalls
the Threlkeld or St. John's mass. If these identifications be
sustained, examples from all the principal intrusive masses of
the Lake District are represented among the boulders of North
Staffordshire. The Borrowdale volcanic series is likewise well
represented, but chiefly by blocks from the fragmental rocks of
the central mountains. The samples include breccias with
angular fragments of pink rhyolite and scattered garnets; banded
fine tuffs, and various other tuffs. Boulders of these materials are
uniformly distributed over the area. The lavas appear to be
less commonly represented, but one or two of the specimens may
be andesites from the Lake District, and there are also some
characteristic examples of the basic lavas of Borrowdale including
basalts with porphyritic augites, streaky garnetiferous rocks,
metamorphosed amygdaloidal basalts, the amygdules occupied
by hornblende, pyrites, quartz, etc.; pink laminated and streaky
rocks sometimes brecciated and resembling the Westmorland
rhyolites.

Rocks from South Scotland are well represented on the high ground round Keele, Maer and Hanchurch. MR. HARKER remarks that these closely resemble the hornblende-bearing granites and tonalites of Galloway. As far as the evidence goes pieces from these Scottish rocks are less abundant on the Cheshire plain round Madeley, while Lake District rocks are there more abundant.

Rocks from Wales are probably represented by some compact felsitic boulders with white crust and evident flow-structures, sometimes containing blebs of quartz and corresponding very well with the rhyolitic lavas of Arenig. A grit resembling closely the unique rock of Ingleton is among a curious collection of large boulders near Shelton-under-Harley. Other grits are represented which, though possibly of Lake District origin, can be matched from the Carboniferous system in various localities.

The occurrence of fragments of marine shells in the drift of (Mr. Wedd.)
North Staffordshire has been known for some time. Last year, however, MR. WEDD succeeded in obtaining these fossils from a number of new localities, and not only from the sands and gravels, but also from the boulder-clay at Dorrington and Betton. Many of his specimens are in a sufficiently good state of preservation to be determined. They have been examined by MR. CLEMENT REID, who recognises among them *Balanus*,

Turritella terebra (*communis*),* *Trophon?*, *Astarte sulcata?* *Cardium edule*,* *Cardium* sp, *Cyprina*,* *Mya*,* *Mytilus*, *Tellina balthica*.*

On the east side of the North Staffordshire coalfield MR. BARROW has obtained good ice-striæ, pointing from N.N.W. to S.S.E., a direction which agrees with the general trend of the transport of erratics in the Leek district. He has met with three examples of ice-worn pavements of grit under drift, but the direction of the striation on these was not satisfactorily preserved. The drift is thick on the top of the watersheds, and thins away rapidly towards the valleys. There is none on slopes of Bunter Sandstone even when these are gentle, and never much upon slopes of Carboniferous grits. Strata that throw out water seem to rid themselves of the drift with comparative rapidity, while on the other hand the drift tends to cling to the more impervious shales.

South Wales.

In the *Annual Summary* for 1897 an indication was given of the general course of the ice-flow southwards from the Brecknock water-parting. It was there pointed out that a great split of the ice-sheet was effected by the Pennant scarp, a portion of the flow passing south-eastward down the Merthyr and Aberdare Valleys, while the remainder travelled south-westward down the Vales of Neath and Swansea. Further examination during last year has shown that this south-westerly flow was even larger than was expected, for it not only reached the sea in Swansea Bay, but over-rode many of the hills along the coast, and rose to a great height on the water-parting between the two vales. These statements are founded not only on the ascertained distribution of the boulders from the north side of the Carboniferous area, but on the discovery of a large number of glaciated rock-surfaces. The survey of the superficial deposits of the whole region is carried on by MESSRS. STRAHAN, TIDDEMAN, GIBSON, and CANTRILL. The following summary of last year's work has been drawn up by MR. STRAHAN.

The descriptions already given of the Drift of East Glamorganshire and Monmouthshire will apply equally to that of the area recently surveyed. At its source it is composed of Old Red Sandstone, and the blocks are subangular; as it passes over the shales of the Millstone Grit it becomes a stiff clay, and picks up vast numbers of blocks of grit, while on the Coal-measures the red tint gradually fades away and the proportion of Coal-measure boulders gradually increases, though Old Red Sandstone, Millstone Grit, and Limestone continue to be abundant right through to the sea. Near its source, moreover, it is generally a tough till, but towards the south it becomes more gravelly, and the boulders become more worn until they may nearly all be

* Forms marked with an asterisk are common.

described as well-rounded pebbles. In parts of the Vale of Neath, which was not only one of the main routes of the ice-flow, but also of the water escaping from the melting ice, the Drift assumes the form of a fluviatile gravel, not distinguishable in appearance from the gravel thrown down by the present river. The Glacial Gravels, however, differ from the post-glacial gravel-terraces in the fact that they have been heaped up in highly characteristic mounds and ridges, enclosing small peat-filled basins once occupied by meres. It is even thought possible by MR. GIBSON that they may once have dammed up parts of the Vale of Neath and given rise to large lakes, for in two places at least gravel-ridges still extend right across with the exception of a narrow notch cut by the river. This possibly is the origin of a deposit of sand which was found to extend to a depth of upwards of 40 feet in sinking the piers of the new railway-bridge a mile above Resolven. (Messrs. Strahan, Tiddeman, and Cantri

The source and limits of a number of local ice-flows, tributary to the main Brecknock sheet, are no less clear than those of the main sheet itself. The deep cwms drained by Rheola and other neighbouring brooks, and by Crynant Brook in the Dulais Valley, are all occupied in their upper parts by great deposits of till, exposed to a depth of 60 feet, and in the last-named of more than 100 feet; the till is crammed with boulders, mostly well glaciated, but all of strictly local origin, derived in fact from the cliffs of the cwms themselves. But in their lower parts the till amalgamates with the Brecknock material and contains a gradually increasing proportion of boulders from that county. Seams of stratified gravel occur in this till, but are far from common. No fragments of marine shells have been seen hitherto in any of the South Wales glacial deposits.

The height to which the Glacial Drift extends seems limited only by that of the ground. Not only till with glaciated boulders, but numerous striated rock-surfaces have been noted by MR. CANTRILL at heights ranging up to 2,000 feet on the Old Red Sandstone dip-slopes. A little below the summit of Fan Fraith a small crag of pebbly grit is striated in a direction S. 35° E., which would lead to the Vale of Neath; at the foot of Fan Hir there are striæ pointing S. 30–50° E. towards the Tawe Fechan. Further west between the Giedd and Twrch striæ run parallel to those rivers, while on Fagl Bengam they occur at about 2,000 feet with a direction S. 10° W.

Further south (Pant Mawr) large patches of bare Millstone Grit show striations ranging to the S.W., but as the ice came within the guiding influence of the Vale of Swansea it took a more southerly course, and at Penwyllt flowed directly down that valley in a direction S. 2–12° W. The Cribarth ridge, however, diverted a portion of this flow, as may be seen by numerous beautiful examples of rock-faces and cornices horizontally striated in a south-westerly direction. In the Giedd and Gwys valleys the flow resumed its southerly course.

Only one example of striated rock in place has been observed on the north side of the Brecknock Water-parting—viz., at

Pont Gihirych in the Crai Valley. The scratches run along the valley in a north-east and south-west direction, but whether up or down could not be determined. Evidence obtained by MR. CANTRILL this year, however, suggests the probability of the ice having crossed the water-parting from north to south. On the sides of the Tawyneu Valley he has noted some large blocks of greenish-grey conglomeratic cornstone, the apparent source of which lies to the north-east of the Bwlch Pen Rhûdd, the pass connecting the Tawyneu and Crai Valleys. In the upper part of the Crai Valley also similar blocks occur, which seem to have travelled southwards—that is, up the valley—from their outcrop.

Further examples of small ridges of morainic material have been met with in some of the cwms and at the foot of some of the precipices. In Cwm Gihirych an irregular mound of such material encloses a peat-flat, probably once a small lake; at the foot of the long straight escarpment of Fan Hir there is a conspicuous ridge, three-quarters of a mile in length and upwards of sixty feet in height. Several more or less indefinite mounds occur at various points below Fan Sir Gaer, two of which enclose lakes—Llyn y Fan Fawr and Llyn y Fan Fach.

Two instances of diversion of rivers by drift from their original courses have been observed by MR. CANTRILL. For example, the Byfre seems originally to have flowed uninterruptedly from its source on Fan Gihirych to the Tawe by way of Nant Byfre, but having been choked with drift about half way along its course, it now disappears down the swallow-hole known as Pwll Byfre, re-issuing from the cavern of Ffynnon Du, a mile and a quarter below Nant Byfre.

Within the limits of the Coal-field striæ have been noted on Hir Fynydd, the water-parting between the Neath and Dulais Valleys, at heights of 1,400 and 980 feet, and on Resolven Mountain, by MR. GIBSON, at more than 1,000 feet; nearer Neath they occur on both sides of the Neath Valley in a position which indicates that that deep depression was filled with ice, probably to overflowing, while the hill of Coed yr Iarll, and others near Briton Ferry, display so many glaciated surfaces as to show that they were completely overridden. Boulders of Millstone Grit, moreover, scattered over high ground indicate that the ice extended further than can be proved by the accidental preservation of striated rock-surfaces. The water-parting between the Dulais and Swansea Vale seems to have been overridden also, at least in its lower parts, for there is a large area of glaciated rock on its crest (nearly 1200 feet above the sea), at the northern foot of Mynydd March Hywel, the striæ ranging W. 30°–35° S., as though the ice had overflowed from the Dulais into the Tawe at this point. Last year similar evidence was obtained of the ice having overflowed from the Vale of Neath into Fforch Dwm, and some striæ, noted by MR. GIBSON in the stream at Hendre Owen-fach as having the unusual direction of N.W.-S.E., may be due to some such local overflow. Near this spot he observed also a beautifully-glaciated boulder of Pennant measuring 14 feet × 9 feet × 3 feet.

A good example of a large transported mass of Millstone Grit occurs on the Neath and Brecon Railway two miles south of Penwyllt. The cutting intersects a small but conspicuous conical eminence on the hill-side, and shows that it consists of slightly broken Millstone Grit in the upper part and of till crowded with well-glaciated blocks of Old Red Sandstone, Millstone Grit, and limestone in the lower part. This is the third example met with in South Wales, the others being the mass of grit exposed in the Sirhowy reservoir and the crag in the Rhondda-fach Valley known as Castell Nos. The last-named, however, is of uncertain origin. (Messrs. Strahan, Tiddeman, and Cantril)

In the Vale of Glamorgan, to the south of the Coal-field, MR. CANTRILL finds characteristic mounds and hollows of gravelly drift east of Welsh St. Donats, and in the valley of the Dawen as far south as Cowbridge. The boulders are chiefly of Coal Measure origin, but a few of Old Red Sandstone occur. Two small outliers of fine gravel and sand near St. Mary Church contain also numerous sub-angular fragments of flint.

MR. TIDDEMAN in the adjoining area to the west has mapped a patch of Boulder-clay about a square mile in extent south of Kenfig Pool, and others both clayey and gravelly in the valley traversed by the Great Western Railway between Stormy and Pyle. Another patch in the Ewenny valley, and extending towards that of the Ogmore, consists of reddish clay with small stones; the greater part of the boulders are Pennant rock, but yellow partly-rolled flints are not uncommon. The clays when most free from stones have been much used for making pots, and are reported to have been worked from Roman times.

The clay is covered with gravels which have a more or less flat surface, and which are not easily distinguished from river-gravels. It is thought by MR. TIDDEMAN that if they were of glacial age and had the moundy outline which characterises the gravels near Llanilid, they must have been subsequently levelled by either river or sea. The latter supposition would imply a submergence in this district of 50 to 100 feet, of which no sufficient evidence has yet been forthcoming.

Isle of Man.

Though the Geological Survey of the Isle of Man has been completed, important information has recently been received regarding the latest (No. 6) of the series of deep borings made in the north of the Isle of Man, which has revealed some points of exceptional interest in relation to the drifts of the island. This boring, the site of which is near the Point of Ayre Lighthouse, only a few feet above high-water mark, was sunk to a depth of 920 feet to prove the extent of the saliferous Keuper Marls which had been discovered in a previous boring. The Glacial series was found to be of unusual thickness, apparently descending to between 470 and 500 feet below sea-level. To the courtesy of MR. J. TODD, under whose supervision the difficult task of (Mr. Lamplugh.)

Mr. Lampugh.) carrying the boring through the drifts was successfully accomplished, we are indebted for a set of specimens from various depths, which have been washed, sifted, and examined.

The following is a condensed account of the section based on this examination, and on the details supplied by Mr. Todd:—

Shingle: Raised beach	16	feet.
Sand and gravel: partly of marine origin, but re-arranged by glacial agencies	97	„
Stony sandy clay, with beds of warp, &c., like that of the cliff sections = boulder-clay series, incorporating marine material	102	„
Muddy sand, silt and gravel, full of shells, one seam containing chiefly *Rhynchonella psittacea;* many of the pebbles coated with nullipora, &c. = a marine deposit	25	„
Reddish sand and gravel, largely made up from the washing of the Triassic rocks of the vicinity; with only a few much-worn shell fragments. A boulder 8 inches in diameter passed through near the base	123	„
Red stony clay, composed of crushed Keuper Marl, with a few far-travelled stones = Lower Boulder-clay	65	„
Reconstructed red marl, with a few subangular erratic pebbles 25 feet above base = glaciated top of Keuper Marl?	70	„
Keuper Marl, disturbed in the upper part, with many bands of salt below 600 feet	422	„
To bottom	920	feet.

The new points brought out by this section are the depth to which the glacial material descends below sea-level; the presence of a local boulder-clay underlying the stratified drifts, made up almost entirely of material derived from the subjacent rock; and the existence between boulder-clays of a thick band having all the characteristics of a true sea bottom, differing from anything recognised in the former boring sections.

Whether the shelly deposit represents a true marine horizon in the glacial series, or is a large transported remnant of the early glacial sea-bottom, cannot, of course, from the nature of the evidence be definitely decided. At the base of the series it is also difficult to determine exactly the limits of the drift, as masses of marl seem to be intercalated with bands in which extraneous pebbles have been mingled with crushed marl.

Isle of Arran.

Mr. Gunn.) The survey of the northern half of Arran has brought to light many proofs that this island was glaciated by the vast mass of ice which moved southwards in the basin of the Firth of Clyde. In the north-west part of the island Mr. Gunn has met with numerous striated rock-surfaces in which the general trend of the striæ is towards S. 10°—20° W. A particularly fine example of a grooved and polished surface of schist may be seen by the roadside immediately south of Whitefarland.

To the east of Auchencar numerous ridges of boulder-clay, or drumlins, run in the general direction of the great glaciation. Relics of a later and more local glaciation also occur in nearly all the valleys in the shape of moraines. They are conspicuous in the valleys at the head of the north Sannox stream, on the north side of Castle Abhail. (Mr. C

In the valley of the Machrie Water about Monyquil and Glaister, and also up the Machrie Burn, mounds of detritus occur which at a distance might be mistaken for moraines, but which when closely examined are found to consist of washed sand and gravel. They are therefore more of the nature of eskers or kames.

Argyllshire.

The glaciation of the Oban district has been further examined by Mr. Symes. The general direction in which, as shown by the striæ on the rocks, the ice has here moved has been from east to west, but every glen, valley, and fiord has a distinct local glaciation. Thus, while the glen at Kilninver, eight miles south of Oban, trends in a direction towards N. 27° W., and has its striæ directed to the same quarter, on the south side of the watershed, where the drainage into Melfort Loch runs in a southerly direction, the ice striæ point to S. 20° W. All the minor striæ then gradually curve westward into the general glaciation as they approach the seaboard. Oban (Mr. S

The boulder clay extends over the district as a thin deposit crowded with huge erratic blocks transported from the east, but it attains a considerable thickness in the glens, where it has been subsequently eroded by streams, and its detritus has been re-arranged in gravel terraces. Some conspicuous examples of such terraces may be observed along the north shore of Loch Scamadale, nine miles south-south-east of Oban. They are composed of stratified sands and gravels, and rise 10 and 31 feet above the loch, which is 221 feet above sea-level. They continue along the valley below the lake as far as Euchar Bridge, sinking gently with the general slope of the river. Associated with these terraces are more recent gravel deposits formed out of the terraces by the action of the stream.

Further eastward in the mountainous district, of which Ben Cruachan is the most conspicuous feature, the mapping of the glacial deposits has been advanced by Mr. Kynaston, who has met with a continuance of the same general features as have already been described in former *Reports*. In the part of the area near Dalmally a large portion of the more low-lying ground is covered with thick accumulations of moraine-drift from the coalescence of the large glaciers that flowed down Glen Orchy and Glen Lochy. Loch and L Etive. Kyna

The Glen Etive area furnishes further ample evidence of the later valley glaciers in the form of morainic material. The River Etive and its tributaries, however, have now eroded their channels, sometimes deeply into the underlying rock, while the morainic

och Awe nd Loch tive. (Mr. ynaston.)

material has been to a great extent rearranged and transported to lower levels. The unusually large size of many of the detrital fans at the mouths of the burns (*e.g.*, along the shore of the upper part of Loch Etive), and the coarseness of the material of which they consist, are very striking. But this is perhaps not surprising when we consider the great capacity for the breaking-down and transportation of material possessed by the torrents during flood-time, and the enormous quantity of more or less loose material at their disposal. The work of these mountain-streams, moreover, is largely assisted by small tributaries, which run over bare rock pitching at a high angle. Down these, and down the numerous "scree-gullies" and "stone-shoots" lining the mountain-sides, the water is poured in torrential cascades during times of heavy rain-fall, pushing on and piling up enormous boulders as though they were small pebbles.

In connection with the effects of running water on the glacial deposits of this region, MR. KYNASTON has reported his observations on recent changes of the river courses, to which reference may be most conveniently made here. He notes an alteration in the channels of such rivers as the Etive, the Kinglass, and the Orchy, which is constantly going on from year to year, where they come out into the lower and wider portions of the valleys. The amount of this alteration can be appreciated by carefully comparing the six-inch Ordnance maps, published more than thirty years ago, with the present course of the rivers and distribution of the alluvial plains. Terraces and alluvial tracts are seen to have been extensively cut away in some places, while fresh alluvium is being laid down in others. The cutting away of terraces, &c., is naturally greatest at the convex side of a bend, and is doubtless due to the increased erosive and transporting power possessed by the river during flood-time, when this action may actually be observed. Such rivers as these rise rapidly, owing to the rapidity with which their tributaries from the surrounding high ground carry off the water from a large area, hence they become exceedingly powerful agents of denudation during heavy rainfall. While mapping the alluvium near the mouth of the Etive, MR. KYNASTON ascertained that the bank of the river along the outer side of a bend had been cut away at the rate of a foot or more per annum.

och Eil istrict. (Mr. rant-Vilson.)

During the past year MR. GRANT-WILSON was able to complete the mapping of the chief portion of the drift deposits within the basin of Loch Eil. These are entirely composed of morainic materials, and both from the size of the moraines, the manner in which they are grouped, and the extent of ground over which they are distributed, they point to the movement of a large sheet of ice from the west. The striæ in the basin of Loch Eil point towards E.S.E.* and show the direction of the ice-flow. On the north side of the loch the moraines are found up to a height of 2,256 feet on the Druim Fada Hills, and pass over the watershed into Glen Loy. On the south side they do not reach above 1,750 feet,

* *Summary of Progress* for 1897, p. 146.

but they pass over the intervening col into the valley of Strone-creggan. Viewed from a distance these drift deposits on both sides of Loch Eil exhibit lines of terraces on a large scale. Loch Eil District. (Grant-Wilson.)

With the exception of a few knolls of rock the whole of the low ground between Banavie and the rivers Spean and Lochy is occupied with moraine drift, and this deposit covers the lower slopes of Ben Nevis up to a height of 1,500 feet.

The greater number of these moraine mounds are composed of fine material. Thus, three miles from Spean Bridge, the face of a large ballast bank on the railway shows 20 feet of false bedded sand and gravel resting on 70 feet of fine gravelly moraine detritus. A mile further south and opposite the Creag Aoile a section may be seen of about 100 feet of fine sharp sand with glacial silt-bands and traces of fragments of decomposing shells.

The wide extent and great depth of these moraines prove how large must have been the body of ice that moved down upon this low ground from the west of Loch Eil, Loch Arkaig, and Glen Albyn. If the valleys to the south and east were at the same time free from ice in their lower reaches, the northern ice might have dammed back the waters of the eastern glens in the manner supposed by MR. JAMIESON in explanation of the "Parallel Roads" of Glen Spean.

From Blairour to the Falls of Mucomir, on both sides of the River Spean, numerous fragments of high-level terraces are to be seen. A cutting on the Fort Augustus railway passes through one of these and shows 20 feet of fine brown glacial silt resting upon blue silt with gravel on the top. These terraces rise up to 270 feet above sea-level, and lie at least 100 feet above the present level of the river. From their position and contents they could not have been deposited by the River Spean. They appear to have been formed at the period when the bottom of Glen Albyn was still filled with ice which ponded back the water above. They doubtless point to a decreasing stage of the glacier which once filled the Great Glen. When this ice-barrier from the north melted, the River Spean would have free scope to sweep away the glacial detritus in its path and to begin the erosion of the rocky gorge in which it is now confined.

Within the moraine area, which stretches from the foot of the Ben Nevis range to the River Lochy, the sites of two large vanished lochs have been mapped. The larger of them lies on the water-shed between the rivers Lundy and Loin, and covers at least a square mile. With the exception of two small remaining tarns the bottom is now quite dry, flat, and about 430 feet above sea-level. The deposits which cover its bottom so far as can be seen are composed of fine glacial silt and sand. The lake was entirely surrounded by moraines. The site of the other sheet of water lies to the north-east of New Inverlochy Castle. A stream flows sluggishly along its length, and numerous sections show its bottom to be filled with glacial silt and sand. Its average level above the sea is 80 feet.

Island of Jura. (Mr. Wilkinson.)

The glacial phenomena of the mainland of Argyllshire are prolonged into the islands that flank the coast, some of which were high enough to nourish their own independent glaciers when the great ice-sheet had sufficiently diminished. In Jura, MR. WILKINSON has found evidence of the march of the mainland-ice across even that lofty island. Along the coast indeed, the striæ indicate that the ice was deflected in its lower portions and moved irregularly along the shore-line. But on the higher ground some large and fine examples of grooved, polished and striated surfaces, which after a passing shower has rendered them wet, reflect the sun's rays with most dazzling effect, demonstrate that over the backbone of the island the ice moved from east to west, varying a little to the north.

Boulder-clay, which has been plentifully deposited, is found banked against the sides of the higher hills and slopes down to the Sound of Jura. Many sections show it to be a stiff clay, often red in colour, with abundant well-rounded and sometimes striated boulders, among which quartzite, epidiorite, dolerite, red sandstone, red porphyry, and andesite are the most common.

The higher corries and glens of the island evidently nursed glaciers after the disappearance of the ice-sheet, for moraine material is abundant there, sometimes even stretching down to the lower valleys.

Connected with at least the later stages of the Ice Age are the Raised Beaches, which form so prominent a feature in the scenery of the west coast of Scotland. The east side of Jura presents a succession of these terraces all along the coast-line from Ardfin in the south of the island to north of Ardlussa House. They lie at various levels, but rarely rise above the hundred-foot contour-line.

It is on the west side of the island, however, that the raised beaches attain their most striking development. They have not yet been completely mapped there, and an account of them is reserved for a future *Summary*.

Perthshire.

Strath-artney, Perthshire. Mr. Cunning-ham-Craig.)

In the Perthshire district, surveyed last year by MR. CUNNINGHAM-CRAIG, which included the basin of Loch Katrine, he found the direction of flow of the ice-sheet to be on the whole towards the south east. He succeeded in establishing this point by obtaining a large number of observations of striæ on quartz-veins even up to the highest hill-tops. He also met with plentiful evidence of later or local glaciation, each glen having its groups of moraines.

Aberdeenshire.

Braemar. Mr. Cunningham-Craig.)

In the area of Braemar, surveyed last year by MR. CUNNINGHAM-CRAIG, the glacial phenomena were traced across the ground between the River Dee and the flanks of the Cairngorm Mountains.

Braemar (Mr. Cunninghan Craig.)

He could rarely detect any rock-striæ that would show the direction of the ice movement; they are scarce and never clear, but the transportation of erratic blocks serves to give a general idea of the flow of the ice-sheet. The best example of this evidence is the occurrence of blocks of the Glen Derry diorite on the hillside above Allanmore, at a distance of more than six miles to the south-east of the parent mass. These blocks could not have been brought to their present position by the later or local glaciation, but must have been transported by the ice-sheet over ridges nearly 3,000 feet in height.

An interesting case of diverted drainage is afforded by Glen Slugain. The upper part of this wide and deep valley contains a mere rivulet of water, which for considerable distances finds its way underneath accumulations of quartzite scree. At the head of the glen a flat expanse of ground is covered with drift and morainic material reaching to the River Quoich, which makes a sharp turn to the westward at this point. It seems that what are now the head-waters of the Quoich used to flow down Glen Slugain, but that during the glaciation the ice descending from the plateau of Beinn a' Bhuird ploughed out the wide east-and-west hollow to the south of that mountain, and with part of the removed material blocked the Slugain valley. The waters of the Quoich were thus enabled to cut back along the hollow south of Beinn a' Bhuird and "behead" the Slugain burn.

At Lochan a' Bhata, situated to the eastward of a col between Glen Dubh and Glen Derry, an interesting deposit has been formed. A flat triangular mass of coarse detritus contains the lochan, the apex terminating in a rocky gorge, while the base presents a very steep scree like face to the glen beneath. This deposit can only be accounted for on the supposition that the main glen (Glen Dubh) was filled by a glacier, against the side of which, or more probably in a small glacial lake formed between the glacier and the hillside, the fan-like mass of material was deposited. The material forming the deposit was brought down by the small burn, which finally occupied and kept open the shallow depression in its delta, which is now filled by the Lochan a' Bhata.

Inverness-shire.

Strathspey. (Mr. Hinxman.)

A full account of the remarkable terraces of Strathspey, by MR. HINXMAN, was given in last *Summary of Progress*. Little of any importance has been met with since to add to that account of the glacial history of this great Highland river. The high level terraces of fluvio-glacial gravel have been found to continue up Glen Truim as far south as Crubinmore, and to rise to a height of 1,020 feet. On the southern slopes of the Monadhliath the moraines that mark the levels of the valley-glaciers are succeeded in many places by hard grey till of considerable thickness.

Ross-shire.

Beauly. (Mr. Hinxman.)

In the Beauly area, to which Mr. Hinxman was transferred for part of the season, he found the hill-slopes and higher parts of the valleys that descend to the head of the Firth to be covered to a great depth with boulder-clay. Thus along the course of the Allt Goibhre sections can be seen showing 80–100 feet of sandy clay. The included stones are mostly of local origin, but there are also many boulders of granite, pegmatite, hornblende-schist, and hornblende-rock, derived from ground further to the west or north-west. Large boulders of a beautiful augen-gneiss and red granite occur in great numbers on the ridge of the Black Isle at Balvaird, near Tarradale. These have been derived from some of the bands of that rock which have been detected among the mountains of eastern Ross-shire.

The 100-feet raised beach forms a wide and conspicuous feature at the head of the Beauly Firth between Tomich and Tarradale House, and its landward margin is clearly defined along the slopes of Clashdorran and Aultavaich. At Muir of Ord it merges into the fluvio-glacial gravels that cover the col between the heads of the Beauly and Cromarty Firths. The beach has been greatly denuded between Tarradale Mains and Redcastle, and only appears in a fragmentary condition, but it can be seen in section capping the sandstone in Redcastle quarry.

Loch Luichart and Black Isle. (Mr. Peach.)

Among the high grounds already referred to as having been surveyed by Messrs. Peach, Horne, and Pocock in the region of Fannich Forest and Loch Luichart, as well as in the lowland of Easter Ross, additional particulars have been obtained regarding the glaciation of that part of Scotland. So thick did the ice remain in many of the higher inland valleys, that there is often difficulty in detecting any satisfactory evidence of the earlier phases of the glacial period. Mr. Peach in the Loch Luichart district last year was unable to find any such evidence. Only on the low ground of the Black Isle in Easter Ross did he come upon undoubted traces of the earlier glaciation. In a sandstone quarry near the village of Conon, striæ were observed by him which pointed E. 20° N. and passed underneath a tough boulder-clay or till, full of well-glaciated blocks of sandstone, Highland schist, augen-gneiss, granite, &c. Above this deposit lies a considerable thickness of looser sandy morainic débris, in which occur large angular blocks of sandstone and occasional boulders of schist, augen-gneiss, &c. Similar phenomena were met with in several places in that part of the region. The striæ and till are attributed by Mr. Peach to the earlier glaciation, while the overlying morainic material is regarded by him as the product of a large glacier which issued from the Conon Valley and spread out upon the Black Isle at the time when the ice reached its greatest extension during the period of the later glaciation. The concentric arrangement of the moraines which cover most of the slope of the Black Isle right up to its crest opposite Dingwall is very conspicuous.

In the mountainous area surveyed by Mr. Peach to the west,

the phenomena which he observed he could only regard as belonging to the later glaciation The striæ, the disposition of the lateral moraines, and the distribution of the carried blocks show that during the greatest extension of the later glaciers a glacier or ice-sheet moved across the watersheds from Glen Fhioding and from Strath Carron into the valley of the Bran, where it received tributary ice across the high cols from the Fannich Valley, swept round Sgurr a Mhullin, leaving the top of that mountain as a "nunatak" or islet, wheeled upon itself on reaching the neighbourhood of Loch Luichart, and, after combining with the main body of ice from Fannich and the Blackwater Valley, issued from the Highlands by the Conon Valley and spread out upon the Black Isle. The blocks of augen-gneiss from Inchbae and Loch Luichart afford excellent material for following the track of the lower part of this combined glacier.

Loch Luichart a Black Isle. (Mr. Peach

The disposition of the terraces of lateral moraine round the hill-tops to the south of the head of Loch Luichart indicates the successive stages in the decrease of this glacier or ice-sheet when the smaller hills (some of which, however, reach a height of more than 1,800 feet) began to appear above its surface as scattered islets. The terraced moraines on the valley-slopes and the succession of terminal moraines along their bottoms, and which bar their streams, plainly mark pauses in the general decrease of the ice, which eventually disappeared leaving the corrie-moraines as its last trace. The terraced moraines are well seen in the neighbourhood of Loch Luichart, but the finest display of them is to be found round the northern flanks of Sgurr a Mhullin, as seen from the railway near Achault, where they appear as a giant staircase to that fine mountain. The terminal moraines are well shown along the line of the railway from Achterneed near Strath Peffer to Achnasheen, though they are most conspicuously displayed between Garve and Loch Luichart Stations.

On the part of the Black Isle, and on the lower portion of the Valley of the Conon, surveyed by Mr. Peach, he found the 100-foot beach to be well marked. Its presence there shows that the ice had retreated inland from the shore either before or during the time when the materials of the terrace were deposited. In the Torridon and Applecross regions of the West Coast, as indicated in previous Reports, the ice continued to descend to the sea long after the time of the 100-foot terrace. In the Black Isle the bluff bounding the upper limit of this terrace truncates the successive concentric moraines. The original flat surface of the terrace is now much furrowed and made irregular by denudation. Sections are thus exposed which show the materials of the terrace to consist chiefly of fine sand and gravel, with sometimes considerable tracts of a finely laminated fawn-coloured clay. Both the fifty-feet and the twenty-five feet raised beaches are well developed on the shores of the Cromarty Firth and along the banks of the River Conon. The deposits consist of sand and clays containing shells, such as cockle, mussel, periwinkle

and other estuarine and littoral species common on our present
and shore. Besides the terrace of the twenty-five feet beach, there are
h.) indications of several smaller fragmentary terraces between the fifty-feet raised beach and the present sea-level, which can only be followed for short distances, but which suffice to prove that the movement of elevation was intermittent, and extended over a considerable period of time. Several well-marked rock-basins occur in the area examined by MR. PEACH, the finest of which are occupied by Loch Luichart, Loch Coulin, and Loch Garve.

In the district of Fannich Forest, surveyed by MR. HORNE,
fr. few striated surfaces were observed on the southern slopes of the Fannich range. A thick covering of drift fills the deep valleys that penetrate the chain, and it forms a gentle slope along the north side of the loch. Several finely striated surfaces, however, were detected at high levels, as, for instance, on the crag at the head of Allt Choire Bhig (about 2,500 feet), where the direction of the striæ is S. 22° E.; on the spur that forms the southern projection from Meallan Rairigidh (between 1,500 and 1,750 feet), where the trend is S. 13°–20° E.; and on the southern slopes of An Coileachan (between the 2,250 and 2,500 feet levels), where the striæ point S. 14°–18° E.

These striated surfaces lie in the eastern portion of the Fannich
ountains, and were evidently produced during a period when
his mass of high ground formed a centre of dispersion for the
ce. There can be no doubt that, as has already been stated, the ice which radiated from the southern portion of the Fannich range crossed Loch Fannich, and overspreading the ridge to the south of that sheet of water, passed into Strath Bran. Quite recently a forest path has been made across this dividing ridge, leading from Achanalt to Cabuie. At various points on the crest of the ridge finely striated surfaces have been laid bare in pit-holes opened in the drift, where the striæ point in a S S.E. direction. The Fannich range runs in an east and west direction for a distance of seven miles, and all the main peaks along the range rise above 3,000 feet. It is obvious that the mass of ice flowing southwards towards Strath Bran must have been considerable, and not improbably furnished the ice-dam that gave rise to the lake-terraces at Achnasheen.

East of Fannich Lodge a deposit of boulder-clay is covered by moraines, while groups of moraines extend westwards to the head of the loch and up the main valleys. No great moraines of recession, or corrie-moraines on a large scale, occur in the ground surveyed by MR. HORNE.

In the portion of the Black Isle mapped by MR. HORNE, which
ıe.) lay to the east of the ground surveyed by MR. PEACH, various striæ were observed which show that the ice there moved in an easterly and E.N.E. direction. The following examples may suffice to indicate the movement—(1) on the hill slope half a mile west of Fortrose E. 6°–14° N.; (2) near Belmaduthy E. 10° N.; (3) near Colbokie, on the west slope of the Black Isle, E. 18° N.

Black Isle. (Mr. Horne.

The evidence of the striated rock surfaces is confirmed by that supplied by the boulders in the drift. Though the greater part of the Black Isle is formed of Old Red Sandstone, a large proportion of the stones in the drift consists of crystalline schists, granite, and other igneous rocks, which have been derived mainly from the high grounds lying to the west. Large erratics of rocks foreign to the Black Isle are of common occurrence, consisting of augen-gneiss or foliated granite, epidiorite, hornblende-schist, and massive grey granite. Attention has been directed to the distribution of these boulders by various local observers in the north of Scotland, and in particular to that of the boulders of foliated granite resembling the Inchbae rock west of Garve, already referred to in the notice of MR. PEACH'S observations, while blocks of this peculiar rock are found in the southern portion of the Black Isle near Tarradale. They become more plentiful northwards in the direction of the Millbuie ridge. If no other locality than Inchbae has been the parent source of these boulders, then the Conan Glacier probably reached the southern margin of the Beauly Firth.

Boulder-clay is distributed over the eastern portion of the Black Isle, where between Belmaduthy and Raddery it forms a gentle slope, but over the western portion extending from Colbokie southwards to Tore a remarkable series of moraines may be observed to form prominent ridges with lochans or marshy hollows between them. In the various pit-sections in these moraines the material is composed of sand and gravel, with an admixture of clay; the stones of foreign origin being associated with large subangular blocks or masses of the underlying yellow sandstone. As these moraines are traced eastwards in the direction of Munlochy they gradually merge into ridges of sand and gravel.

In the Fortrose region the 100 feet, 50 feet, and 25 feet raised beaches are admirably displayed. They may be followed at intervals all round the southern portion of the Black Isle to Tarradale.

Loch Fanni and Beinn nan Ramh district. (M Pocock.)

The glaciation at the east end of Loch Fannich, and also that of Beinn nan Ramh to the south-west of that sheet of water, were examined last year by MR. POCOCK. In the first of these two tracts he obtained a fairly complete set of observations of rock-striæ in illustration of the movement of the ice at different stages of the Glacial period, but very few were found in the Ben Ramh area. The finest examples can be seen on the quartzose Moine-schists by the roadside at the foot of Loch Fannich, and at the top of Aultdearg Wood. The greater number of striæ in the area towards Loch Luichart point a few degrees south of east. But an older set, somewhat obscure, is indicated by cross hatches, obtained at a height of 1,500 feet, on the shoulder of Ben Dearg. These point in a southerly direction, and may belong to the period of the lowland boulder-clay. The easterly striæ indicate an epoch of intense glaciation, during which the top of Ben Ramh, with the more formidable barrier of Ben Fionn behind it, served to divide two ice streams, one of

Loch Fannich and Beinn nan Ramh district. (Mr. Pocock).

which has been already alluded to as having moved into Strath Bran, while the other crossed the peaty plateau on the west in the direction of Loch Maree.

Beyond the east end of the Fannich range striæ were obtained on the summit of Ben Dearg at a height of more than 2,000 feet, showing that the ice from the north side of the Fannich ridge crossed the hill-top without deflection. The ice from the south side of that ridge, instead of following the course of the Grudie River, passed straight over Càrn na Bèiste at a height of 1,680 feet, and, descending the east side, crossed the Grudie Valley at an oblique angle. These two streams must have coalesced on the lower ground east of Ben Aigean.

A later stage of glaciation is indicated by repeated instances of cross hatching in the striæ, found in the lower ground of the Loch Luichart district, in which a newer set of striæ, following the course of the valleys, obliterates the older set pointing across them to the east. At this stage the ice of Loch Fannich passed round the north side of Càrn na Bèiste along the course of the Grudie River, while tributary streams from the north descended the valleys on either side of Ben Dearg.

Moraines of recession, belonging to the last stages of the Glacial period, are fairly common in the Grudie Valley, but they are low and inconspicuous, being, probably, an old series that has undergone much denudation. Boulders of flaky garnetiferous gneiss, strewn over the tops of these moraines, have come from the rocks which crop out near the head of Loch Fannich.

A far more conspicuous set of moraines occurs in the valley between Ben Aigean and Ben Dearg. One of these, which is upwards of 20 feet high, extends across the mouth of the valley for a distance of about a mile; another curves round the great corrie of Ben Aigean, while a third set runs up the valley in a direction more or less parallel to the Ben Aigean cliff. Moraines are found also on the west side of Ben Ramh, with occasional boulders of garnetiferous flaky gneiss, derived from the hill top, while in the Strathcromble Valley on the south side of the hill another group occurs which has been formed by the corrie glaciers of Ben Fionn.

Caithness.

(Mr. Pocock.)

In the Braemore district, Caithness, surveyed last year by MR. POCOCK, no facts of special interest were observed in the glaciation of this county. The greater part of the ground examined, with the exception of the Morven Hills, is covered by boulder-clay of the usual type, consisting of subangular boulders, striated in the direction of the ice movement, and set in a matrix of tough clay, which is red and sandy where it lies on the Old Red Sandstone, but becomes grey and granitic where it rests on granite. The rock-striæ, as well as the transported boulders, indicate an eastward movement of the ice. The shelly boulder-clay hardly comes within the area recently surveyed, but a blue boulder-clay similar to that from which ROBERT DICK obtained

marine shells in the Dunbeath Water occurs as far west as Pollroy. Moraines belonging to the later phases of glaciation are not common, the wide open strath to the north of Morven being unfavourable to their formation. They were observed in only two places, viz., a short distance above Braemore, and two miles down the Berriedale Water from Goberniesgeach. (Mr. Pocock)

Island of Skye.

The progress of MR. HARKER'S mapping in and about the Cuillin Hills, and on the moorland ground farther north, has given more detailed information concerning the glaciation of this central part of Skye, which, as already pointed out in former Reports, was due wholly to local glaciers. At the epoch of maximum glaciation only the highest summits of the Cuillins stood above the ice. This is true also of Blaven, and probably of the Red Hills, though the crumbling granite of which these latter are built is not fitted to preserve the evidences of glaciation. The main range of the Cuillins, with its prolongation north-eastward and eastward to Sgùrr nan Gillean, was then, as now, a line of divide; but elsewhere among the mountains the ice did not always follow the present drainage-lines. The mountain area is divided by a broad double strath, formed by the Sligachan Valley running northward and the Camasunary Valley running southward, with a low watershed (250 feet) between them. The Sligachan River is fed chiefly from the west, especially from Harta Corrie, which drains the interior of the northern part of the Cuillins; the Camasunary River is fed chiefly from the east, from the corries between Marsco and Blaven. In Glacial times, however, the great glacier from Harta Corrie divided, part going northward and part southward, over Druim an Eidhne and along the eastern side of Coire Riabhach. Similarly the ice from the eastern mountains divided, part going towards Sligachan and part towards Camasunary. The low watershed was thus at once the meeting-place of two ice-streams from west and east, and the parting of two streams to north and south. These must both have been of considerable magnitude. The northward-moving glacier, on reaching the mouth of the valley at Sligachan, spread out like a fan. On the left hand it became confluent with the smaller glaciers from the northern corries of the Cuillins—Coir' a' Bhasteir and Fionn Choire—and the united stream flowed westward into the upper part of Glen Brittle, over-riding the pass (1,150 feet) north of Bruach na Frithe, and leaving striæ directed westward on the ridge of that mountain. The main body of the Sligachan glacier, however, spread out over the moorland tract, following especially the Drynoch valley westward towards Loch Harport and the Varrigill valley northward towards Portree. The midstream-line can be traced out by the preponderance of gabbro boulders (derived mainly from the left side of the Sligachan valley) on one side, and of granite (derived from the right side) on the other, in the drift deposits. By taking a census of 200 or 300 boulders at each selected spot, of which Cuillin district. (Mr. Harker)

Cuillin district. (Mr. Harker.)

more than ninety were chosen, it was found possible to draw this line with precision. After following the middle of the valley it swings round westward at Sligachan, and runs for some miles close to the Dunvegan high road. This westward diversion of the ice-stream is in itself enough to suggest that the natural outlet sea-ward by Loch Sligachan was more or less obstructed by the ice-sheet from the Scottish mainland, which hugged the eastern coast of Skye. It even seems probable that at one stage a tongue of the Scottish ice was forced up Loch Sligachan, for near the head of the loch occur boulders of Torridon Sandstone and other rocks which must have been derived from the east. At a later stage this extraneous pressure was apparently relaxed, and a second set of striæ along the shores of the loch indicates a freer outlet in that direction. To this stage are probably to be referred the large erratics scattered over the surface. When these are examined in the same way as the boulders in the hummocky drift, and a line is drawn to divide preponderant gabbro from preponderant granite erratics, it is found that this line does not turn westward at Sligachan like the other, but continues northward very near to the Portree road, thus indicating a relief of the pressure from the east.

The glacier flowing southward from the central divide was probably not less powerful than that flowing north. It evidently filled the Camasunary valley to a great depth. On the left side the slopes of Blaven are glaciated nearly up to the crest-line, while on the right Sgùrr an Eidhne (1,390 feet) and Sgùrr na Stri (1,623 feet) are moulded and polished by ice to their summits. The evidence of the striated surfaces, which are so conspicuous all over this neighbourhood, is confirmed by the distribution of the boulders. Granite from Ruadh Stac and Marsco is found not only along the valley but on the western slopes of Blaven. The most westerly granite *in situ* is at Meall Dearg, on the right side of the mouth of Harta Corrie. A line drawn from here S.S.E. and S., following the direction of the striæ, defines the western limit of erratics of granite. This line passes a little east of Loch a Choire Riabhaich and along the ridge of Sgùrr na Stri. The striæ so clearly preserved on the gabbro indicate, however, a still further westward spread of this glacier, showing that it obliquely crossed the south-eastern part of Druim nan Ramh, at a height of over 1,300 feet, into Coruisk itself.

The Coruisk valley, receiving the whole of the interior drainage of the southern and major portion of the Cuillins, was occupied by a great glacier, which, at its highest stage, was only just held in on the west by the main summit ridge, while on its east side it marched with the Camasunary glacier just described. That the latter was able to a certain extent to encroach upon the territory of the Coruisk glacier is indeed the best evidence of its important magnitude. Nowhere perhaps in Britain is there a more striking display of ice-moulding and glacial striations than on the rocks of naked gabbro which surround Loch Coruisk and border the adjoining sea-loch Scavaig. Loch Coruisk itself is a

rock-basin with a maximum depth of 96 feet, going down therefore 70 feet below the sea-level. The striæ, which extend almost continuously over all the surrounding slopes, seem to indicate an accumulation of ice which found exit only with difficulty through the narrow outlet. The difficulty arising from the form of the ground would be augmented by the pressure on the one hand of the Camasunary glacier, and on the other of the smaller glaciers which from the corries south of Sgùrr Dubh converged more directly upon the head of Loch Scavaig. At several points about the outlet of the Scavaig River, however, a second set of striæ running S.S.W. seems to indicate that at a certain stage the Coruisk ice and the smaller glaciers from the west may have shrunk sufficiently to allow a branch of the Harta Corrie glacier to pour more freely down Coire Riabhach and across the foot of Loch Coruisk to the sea. Cuillin district. (Mr. Harker.

The accumulations of boulders, large and small, which occupy many of the higher corries are often scarcely to be separated from the screes; and indeed these latter, though still receiving additions from the steep mountain slopes, probably date back in part to Glacial times. The drift-deposits proper, which run up the valleys to altitudes of 1,000 or even 1,500 feet, and overspread a considerable part of the moors to the north and west, fall under two distinct types. There is first the hummocky drift or "kettle moraine," noticed in the last *Annual Summary*. This does not, as a rule, extend far up into the mountain tract, but is found occupying the lower and more level parts of the valleys, and spreading over considerable areas of the more open country. Boulders varying in size usually compose the bulk of the mass; they are mostly subangular, but rarely scratched. The second type of drift is sharply distinguished from the first by the smooth flowing outlines which it imparts to the hills, contrasting with the irregular surface, holding numerous tarns and swamps, which is characteristic of the "kettle moraine." This smooth-surfaced drift goes higher up the valleys than the hummocky kind, occurs as a fringe to it, and extends beyond it away from the mountains. It sometimes attains also a greater thickness, exceptionally as much as 100 feet. In the valleys of the basalt country, where it is most developed, it consists usually of a reddish sandy clay enclosing small boulders, and some larger ones, the latter often striated.

The distribution of the hummocky drift and the circumstances in which it occurs support the view that it represents the material—subglacial, englacial, and superglacial—thrown down by stranded portions of glaciers cut off from their supply behind and melting as they stood. The same supposition explains the absence of moraines of recession. The largest area of this "kettle moraine" extends from Harta Coire northward to near Garadubh on the Portree road, a distance of ten miles. It sends an arm westward up the valley of Allt Dearg Mòr and another over into the Drynoch valley, but these do not extend farther than a mile and a mile and a half respectively. Its extension thus connects it with a late stage in the sequence of events, when the general

Cuillin district. (Mr. Harker.)

movement of the Sligachan glacier was towards the north; while an examination of the boulders, as remarked above, shows that the material was brought down during the maximum glaciation, when the flow trended more westward. This accords with the supposed mode of origin of the "kettle moraine," and confirms the view that there was no break between the two stages of glaciation which for convenience have been distinguished.

Again, there is an evident connection between the "kettle moraine" and the surface erratics, often of large size, which are scattered over the ground. These generally occur in large numbers on the hummocky surface, but are scarcely found beyond its limits. It is a common observation, too, when a hummock is exposed in section, that the larger boulders in it occur towards the top.

Ireland.

Wicklow and Wexford. (Mr. Nolan.)

In continuing his revision of the superficial formations in the counties of Wicklow and Wexford, MR. NOLAN has found that the western flanks of the granite range display much less local drift than is found on the eastern and northern sides. The hills, too, present some different features. There is a general absence among them of cliffs, of deep and narrow valleys, originating in abrupt semi-circular basins like those of Glenmacnass and the Moraine Glen, and corries with mountain tarns situated at the foot of lofty precipices.

The declivities on the western side are much gentler, and are covered with an almost unbroken mantle of moor and peat-bog. Nor does the local drift usually attain such heights as it does in the districts to the north and east. In the valley of the Liffey, south east from Kilbride, it seldom ascends higher than from 900 to 1,000 feet, rising to 1,100 in the upper part, called the Glen of Kippure, and its branches. This deposit is a sandy boulder-clay, almost altogether made up of granite blocks and detritus, with some of slate or schist. In the Glen of Kippure, however, a pebble of black chert, such as is common in the limestone gravel, was found at a height of 1,100 feet, but it must be remembered that this kind of drift occurs at a greater elevation on the Dublin mountains, a few miles to the north.

A considerable spread of local drift is again met with at Lackan, some four miles to the south of Kilbride. The physical features of that neighbourhood are peculiar. The village stands on the flanks of a hill that forms the northern boundary of a great amphitheatre of mountains, of which Mullaghcleevaun—the second highest summit in Wicklow—is the culminating height. The line of elevations is continued by Moanbane, the Black Banks, and the hills south and west of Blackditches to Hollywood, from which a low ridge extends northwards to Baltiboys. A considerable area of low flat ground is thus enclosed, which, viewed from the neighbouring heights, appears to be so level a plain as to have led some observers to consider it as marking the floor of an ancient lake, particularly as deposits

of brown and leaden-coloured calcareous and tenacious clay, with fragments of shells, are occasionally met with under the local drift. This latter generally makes flat or slightly undulating ground, the central portions being covered with peat-bog. The average height of the drift here is about 700 feet, but it rises to 1,000 feet at "The Lodge" in the small valley to E.S.E. of Lackan. Wicklow and Wex (Mr. No

Southwards of this district to the foot of the hills that stretch westward from Wicklow Gap, the drift has been noted by MR. NOLAN only in occasional patches, the ground being rocky or moory, and strewn with numerous granite blocks. At Lockstown, however, it forms a remarkable terrace of granite detritus 29 feet high and extending for nearly a mile north-westward along the valley of the King's River.

The comparatively low-lying and cultivated country to the west of all this district is mainly covered with limestone drift of the same kind as that which prevails on the eastern side of the granite chain and generally over this part of Ireland.

Although rock-corries form no usual or conspicuous part of the scenery on the west of the granite range, mention must be made of a remarkable one at Mullaghcleevaun, where a mountain occupies a central position on the granitic highlands. The corrie is situated close to the summit, under precipices that face to the north-east. This deep and lonely hollow contains a small tarn called Cleevaun Lough, the waters of which are dammed up on the outer side by a mass of local blocks and débris, forming a small semicircular ridge.* Its position at a height of 2,244 feet under cliffs that tower 500 feet above is remarkable as testifying to the thickness of the ice-sheet, which must have covered even the highest of the Wicklow Mountains.

RECENT.

It is seldom that any novel features of interest or importance have to be reported regarding the more recent geological formations encountered by the Geological Survey. Last year progress was made in mapping the marine terraces in the south of England and along the western and north-eastern coast-line of Scotland. The superficial accumulations in the southern non-glaciated part of England were further mapped, and the peat-mosses in central England, the north-west of Scotland, and the east of Ireland were likewise traced on the large-scale maps.

Taking the south coast of Cornwall from Falmouth as a centre, MR. HILL has traced frequent marine terraces between Gerrans Bay and Helford River, of which perhaps the best example is the raised beach of Pendower in Gerrans Bay. A distinctive feature of these terraces is to be found in the compactness of the material of which some of them are composed. It is often so cemented together by iron-oxide as to simulate the appearance Cornnw (Mr. J. Hill.)

* This little moraine has been already noticed by Rev. M. H Close. *Journal Roy. Geol. Society, Ireland*, vol. v. part 1, p. 74.

ornwall. (r. J. B. ill.)

of some of the older geological formations, and in some districts it has served the purpose of building-stone. Even on the coast-line where the beaches are absent, a tiny fringe of gravel is often preserved. It may be observed running along some of the steeper cliffs, its preservation being obviously due to the durability of the cementing material, which has not only held the particles together, but has firmly bound the gravel to the rock on which it rests. The upheaval which has left these terraces in their present position has often materially changed the geographical features; for instance, the present peninsula of St. Anthony, above two miles in length, was before the uprise an island, as is demonstrated by the deposits of sand charged with marine shells on the neck of the peninsula.

These raised beaches are often overlain by the material which has long been known in Cornwall and to geologists generally as "head." This deposit is sometimes stratified, and may contain beds of fairly rounded gravel; more often, however, the tendency to stratification is but slight, and the deposit presents an irregular accumulation of stones, mostly angular, occasionally sub-angular. Such an accumulation is made up of material similar to the ordinary sub-soil of the district. If this sub-soil were transported from higher to lower levels it would probably form a deposit similar to the so-called "head," which often merges so gradually into the sub-soil as not to be separable from it.

rset. r. nxman.)

Much of the ground where the Chalk rises to the surface is covered with a deposit which has long been known under the name of "clay-with-flints." In recently revising the maps of Dorset, MR. HINXMAN has found that the greater portion of the high chalk-plateau which extends on either side of the Frome valley is covered with a deposit of orange or red clay, very stiff in the lower portion, but passing into a brownish loam near the surface. This deposit rests irregularly on the surface of the chalk, and varies from a few inches to 6 or 8 feet in thickness, with an average depth of about $2\frac{1}{2}$ feet. It is always more or less filled with angular chalk-flints irregularly disposed, though here and there a parallel arrangement of them can be detected. The upper portion of the clay often becomes gravelly, from the admixture of rounded pebbles of flint, jasper, vein-quartz, and quartzite. These materials have no doubt been derived from the waste of the Bagshot Gravels. Small deposits of sand and gravel are also found in several places, occupying shallow pipes or basins in the clay. The clay-with-flints shows no evidence of glacial action, and must be regarded as a *remanié* deposit derived from the waste of the Chalk and overlying Tertiary sands and gravels.

In the Bristol Channel, owing to the great vertical range of the tides, large tracts of low land are laid bare at low water, and these are more or less deeply coated with the silt and mud carried

ıthWales. r. ahan.)

down into the estuary by the Severn and other streams. During the past year considerable tracts of such tidal alluvium have been mapped along the coast of South Wales. Some of these, such as Aberavan Marsh, lie behind the sand-dunes and must be of considerable antiquity. The tract in front of Aberavan has been

artificially drained; some sections at the east end were described in the *Annual Report* for 1896 (p. 84, Port Talbot). The Neath is tidal as far up as Aberdulais and its alluvium consists of blue estuarine clay used for brickmaking. The river escapes to the sea at Briton Ferry, but there is an equally good outlet for it along the alluvial flat on the west side of the Pennant hill of Coed yr Iarll. As recorded by MR. CODRINGTON* the rock was reached at Neath at a depth of 52 feet below clay, peat, and gravel, and in the piers of the Rhondda and Swansea Bay Railway Bridge at depths of 28 to 55 feet below low-water mark, the material here being partly alluvial and partly of glacial origin. South Wal (Mr. Strahan.)

From the mouth of the Neath to that of the Tawe the shore is bordered by the range of sand-dunes known as the Crymlyn Burrows, behind which is enclosed another marsh a quarter of a mile in width at Jersey Marine, and extending two miles inland in Crymlyn Bog. A borehole put down near high-water mark at a point south of Halfway House reached the rock at a depth of 58 feet, after passing through 40 feet of sand underlain by some clay and gravel.

The Crymlyn Burrows are growing seawards in their western part by the formation of new low dunes south of the high water mark. The Baglan Burrows are spreading south-westward in a similar manner, but the Aberavan Burrows have been newly breached by the wind here and there in a manner which suggests that they are perhaps retreating landward.

A well-marked river-terrace forms the ground on which the southern end of Bridgend is built. It extends, with only one break at Coity Brook, on the left bank of the Ogmore from opposite Angeltown to near Merthyr Mawr. Others occur higher up the stream. The Vale of Neath contains a series of "fans" of gravel, brought down from the deep drift-laden cwms on either side of the valley and spread out as deltas on the alluvial flat below. Almost every fan has been utilised as a building site. One of the largest is occupied by Resolven.

Reference has already been made to some of the higher raised beaches on the coast of Scotland which were formed during the later part of the Ice Age. The most conspicuous of these are the 100-feet and 50-feet beaches, both of which play an important part in the coast scenery of the country. Besides these, however, other terraces occur at lower levels and also form prominent features along many parts of the sea-board. Nowhere are they more strikingly displayed than in the basin of the Firth of Clyde. During last year MR. GUNN traced the 25-feet beach as a narrow terrace along the north-west and north coasts of the island of Arran, sometimes as a platform of sandy and gravelly sediment, elsewhere only a shelf cut out of the rocks and studded with old sea-stacks, as at Imachar. Here and there, as at the Scriodan, near the north end of the island, the terrace is obscured by landslips. Generally a marked rocky cliff rises at the back of the terrace, in which caves are frequent. Little evidence of the Arran. (Mr. Gunn

* *Quart. Journ. Geol. Soc.*, vol. liv. p. 254 (1898).

Arran. (Mr. Gunn.) higher beaches is observable along this coast except near the mouths of some of the streams, as at Lochranza, Catacol, and at Iorsawaterfoot. The 100-feet beach is very conspicuous at the last-named place. Several other marine terraces may also be observed intermediate between it and the 25-feet beach.

Argyllshire. (Mr. Symes.) On the Argyllshire coast similar phenomena have been observed. Raised beaches have been admirably preserved in many of the fiords and glens. At Kilmelfort these terraces cover a considerable area, the 100-feet beach being well-marked among them. Some of the beaches contain abundant marine shells, as on Easdale island. Again, a large cave, with two exits, has been found on Eilean nan Caorach, an islet in the Sound of Lorne about ten miles to the south-west of Oban, where the floor is covered with a stalagmitic incrustation and numerous shells. For some years past attention has been directed to the caves in the line of old sea-cliffs at the inner margin of the terrace on which the lower part of Oban is built. A new recess or rock-shelter of this kind, which was opened last year near to the railway-station, was found to have on its floor an accumulation in which bones of birds and other animals, shells, ashes, and pieces of flint were found.

Ross-shire. (Mr. Peach.) While mapping the Loch Luichart and Easter Ross district last year MR. PEACH had occasion to observe the action of some of the rivers in carrying down and spreading out their alluvia. The various rock-basins of that part of the country are being rapidly filled up by the amount of detritus annually poured into them. Among the streams the River Bran may be singled out as having played a double part. On the one hand, at the lower end of Loch Coulin it has cut down the barrier and lowered the level of that sheet of water so as to isolate from it Loch Achanalt, which, as shown by the alluvial terraces on the present barrier was obviously once connected with it. On the other hand, at the upper end of Loch Coulin the river has silted up the lake and has spread out the great alluvial plain which stretches for some miles to the west. A considerable alluvial plain surrounds the head of Loch Luichart, formed of sediment principally brought down by the Grudie Water. The main branch of the Bran, or Conon, as it is here called, issues from Loch Coulin filtered and almost free from sediment. At the head of Loch Garve a wide plain of alluvium has been formed by the Black Water which is fast filling up the lake. In a lower part of its course the same river, by cutting the gorge in which the falls of Rogie occur, has considerably lowered the level and diminished the area of Loch Garve. The successive shores of the lake while it was being drained and the ravine was being deepened are marked by beach-deposits, which reach down to the top of the gorge.

Wicklow. (Mr. Nolan.) An important feature in the recent revision of the Geological Survey maps of the East of Ireland has been the mapping of the areas of peat which were not originally represented on the maps. The outlines of the extensive mantle of peat that covers so much of the Wicklow Mountains have now been completely traced by

MR. NOLAN. This irregular tract extends from Killakee Mountain, in the vicinity of Dublin, to Lough Nahanagan near Glendalough, a distance of 14 miles, having an average width of from 6 to 7 miles. Its general character was described in the last *Summary of Progress*. Peat-bog again appears capping the cliffs that rise steeply over Lough Nahanagan on the south, and extend north-westwards, forming the southern boundary of the upper part of the valley of the King's River. The peat is often 10 or 12 feet thick, but it has been much denuded and presents a ragged surface. It covers the flat top of the mountain behind the cliffs, and also extends westward by the head of the Valleys of Glendalough and Glenmalure to the Table Mountain at an average elevation of 2,200 feet. Wicklow. (Mr. Nolan

The flat bogs are of no great extent; the chief of them has been already referred to as occupying the centre of the plain south of Lackan. This bog consists of two main portions having a combined length of two and a quarter miles by an average width of one mile. The turf is much used for fuel.

NEW RAILWAY-CUTTINGS.

The cuttings made for lines of railway often supply invaluable evidence to the geological surveyor. But unless visited soon after being opened they are apt to be earthed over, sown with grass, or otherwise obscured, unless where they consist of rocks of sufficient durability to retain a vertical face. Consequently, it has been the practice of the Geological Survey to examine such excavations during their progress or soon after their completion, and to take advantage of them for future maps or for the revision of already published sheets. It is desirable that a record should be kept, for public use, of all such new artificial sections, and it is proposed to publish notes of them from time to time in the *Annual Summary of Progress* of the Geological Survey.

During last year a number of new lines of railway have been in course of construction in different parts of the country. Their cuttings have been examined by members of the staff of the Survey and the following notes of the sections have been prepared by them.

Great Western Railway.—This railway company is now engaged in making a more direct route to Exeter, by Newbury and the Vale of Pewsey. The cuttings along this new line from Stert near Devizes to Westbury in Wiltshire, have been examined by MR. WOODWARD and MR. BENNETT. (Messrs. Woodward and Bennet

To the east of the Clock Inn at Stert a cutting showed the Gault-clay overlain by an irregular and not persistent deposit of chalky clay or marl from 3 to 6 feet thick, rarely as much as 10 feet. This deposit was in places covered with stiff brown or grey clay. Usually the base of this surface-accumulation was formed of a rubble of chalk or of rounded chalk stones, occasional bits of flint, fragments of Upper Greensand, and greywether. In some places there was a marly deposit without any stones, while in others the cutting showed simply a white-washed clay, the

Messrs. Woodward and Bennett.) joint-surfaces and cracks in the clay being coated with carbonate of lime derived from adjacent or formerly overlying deposits of marl. Occasional land and freshwater mollusca were met with. Accumulations of this nature occur here and there all the way from Stert to East Coulston; at the last-named locality the marly deposits rest on the Kimeridge Clay. For the most part they may be looked upon simply as relics of the denudation of the Chalk, Upper Greensand, and Gault.* The railway-cuttings showed that they occur as patches or pockets in old hollows, and the fact that much of the material has been decalcified renders it impossible to map such a soil with any approach to accuracy. The character of the land has, however, been greatly modified between Stert and Patney, and between Etchilhampton and Wedhampton, where this irregular clayey soil overlies the Upper Greensand.

In the cutting south and south-east of the Clock Inn at Stert, the stiff Gault-clay was to be seen passing upwards into somewhat sandy and dark greenish clay—the passage-beds into the Upper Greensand. Between Marsh Farm and Ruddlebats Hanging the cutting showed stiff Gault-clay. Further on to the west of Sparrow Cottage and for some distance the railway traverses slipped masses of Gault and Upper Greensand, and the scarp above shows a great slipped mass of Greensand. A little tract of Upper Greensand has been cut through at Fiddington Farm.

Further south the railway crosses the Gault north of Littleton Pannel and Great Cheverell. North-east of Home Farm a cutting shows the Gault-clay with ferruginous base, resting on the Portland Sands. Eastward the Gault is covered here and there with the irregular chalky Drift and débris of Upper Greensand, to which reference has been already made. Westward the Portland Sands, comprising green, yellow, and buff sands, have been opened up to a depth of 15 or 20 feet. No junction with the Kimeridge Clay was laid open. The clay has been exposed in the shallow cuttings north of East Coulston.

To the south-east of Lower Baynton Farm the Kimeridge Clay is covered with a patch of stiff chalky clay or marl, while by the stream north of East Coulston there is a local deposit of fine chalk gravel, with occasional fragments of greywether. In a subsequent examination MR. BENNETT observed that near Bratton a long cutting has been excavated in the Gault, surmounted in places by 8 or 10 feet of chalk-rubble and flint-gravel; and that this superficial chalky drift occurred on the low grounds opposite to the valleys at Tinhead and Bratton, whence it had evidently been derived.

South Wales Direct Railway.—The cuttings on this new line have been examined by MR. H. B. WOODWARD. The Railway diverges from the old main-line of the Great Western Railway a

* It is quite possible that some of the chalk-rubble is a relic of former agricultural operations. In old times it was not unusual to put 160 cart-loads of chalk on an acre, on both sandy and clayey lands. Davis, Agriculture of Wilts, 1794, pp. 63–65.

quarter of a mile west of Wootton Bassett, and extends for a distance of about 28 miles to Patchway, south-east of the Severn Tunnel. In a deep cutting which traverses Hunt Mill Lane near Wootton Bassett rubbly coral-limestones and clays of the Upper Corallian dip southwards at a considerable angle and are overlain by dark blue Kimeridge Clay. No evidence of the fault (shown on the Geological Survey map) was here observed, but the cutting was far from clear owing to débris covering the slopes. (Mr. Woodward.)

On the western side of Hunt Mill Lane there is a deep cutting in the Oxford Clay; and a similar cutting south-east of Whitehill Farm shows Oxford Clay with large specimens of *Gryphæa dilatata*. The next cutting on either side of the main road north of Dovey's Farm is also in Oxford Clay.

In the neighbourhood of Brinkworth several cuttings have been made in stiff grey clay and shales with cement-stones belonging to the Oxford Clay; covered here and there with two or three feet of clayey soil with flints, mostly subangular and angular.

This surface-Drift was well shown to the south-west of Brinkworth, where it occurs at a height of about 250 feet or more above sea-level, but not more than about 30 feet above the Brinkworth Brook. It is evidently a low-plateau gravelly drift, but it has no connection with the present stream. The valley-gravel which occurs further west on the borders of the River Avon is an oolitic gravel, made up largely of rolled and flat oolitic stones. The higher drift is almost entirely if not wholly an angular flint-drift.

Mr. Woodward picked up five stones which appeared to him to resemble the Eoliths obtained from the plateau-gravel at Alderbury Hill near Salisbury. These were sent to Dr. Blackmore, who writes, "Three are undoubted Eoliths, which I can match from Alderbury and other localities."

South of Little Somerford no cuttings were opened in the ground, but it is of a clayey nature. West of the road leading to Great Somerford four feet of sand were exposed in a cutting just commenced, and this sand no doubt belongs to the Kellaways Beds. Evidence of this group had been previously obtained at the adjacent Cemetery.*

On the west side of the River Avon and south-east of Angrove Cottages the rail passes over three or four feet of alluvial loam resting on oolitic gravel, with flat pebbles of limestone, etc. To the north and north-east of Bincombe Wood, south of Corston, a cutting about 20 feet deep displayed clay with septaria overlain by 10 to 20 feet of sandy and loamy beds, all belonging to the Kellaways division. From the clays Mr. Woodward obtained *Ammonites Kœnigi*, *A. gowerianus*, *Cardium* and other lamellibranchs, and selenite. No doggers were seen in the sandy Kellaways Beds. The Cornbrash was exposed east of Kingway Barn. From the west of Kingway Barn

* Memoir on Jurassic Rocks of Britain, vol. v. p. 30.

ward.) to about half a mile west of Bradfield Farm, north of Hullavington, excellent sections of the rubbly Cornbrash were exposed to a depth of from five to ten feet. West of the Gauze Brook the Cornbrash was seen to overlie 12 feet of blue clays belonging to the Forest Marble, and these clays were exposed here and there on the slopes bordering Gauze Brook and in the valley a little further east.

To the south of Norton a cutting was made in the Forest Marble clays with some stone-beds, sands and doggers, the whole inclined gently towards the east.

Adjacent to the road from Townleaze Barn, 20 feet of shales with layers of sandy limestone exhibiting track-marks were exposed. Across the belt of Forest Marble the cuttings were few and of little interest. To the south-west of Furleaze Farm the soil is a red and brown brashy clay.

South of Cream Gorse thin sandy limestone and clay, and south-west of Low Barn grey clay and shelly oolitic limestone, were to be seen. On the west side of the road, between Alderton and "Elm and Ash," a shaft was sunk 30 feet mainly in stiff grey clay. Thence to Acton Turville and about half a mile west of the village there were occasional indications of clay, thin sandy limestone, and oolitic and shelly limestone belonging to the Forest Marble. Here and there a swallow hole has been noted on the Ordnance maps, where the surface-water is conducted through a thin capping of Forest Marble into the underlying Great Oolite.

A tunnel about 2½ miles in length is in course of construction through the Cotteswold Hills between Acton Turville and Old Sodbury. This tunnel traverses the strata from the base of the Forest Marble to the upper portions of the Lower Lias. Seven shafts have been sunk along the line of the tunnel, and much water was encountered. The following details of the water found in these sinkings were communicated by MR. W. GREGORY:—

Shaft No. 1, north of Newhouse Farm, through base of Forest Marble into Great Oolite. Depth 111 feet. 3,000 gallons of water per hour.

Shaft No. 2, south-east of Lyegrove Farm, through Great Oolite into Fuller's Earth. Depth 148 feet. 350 gallons per hour.

Shaft No. 3, south of Lyegrove Farm, through Great Oolite and Fuller's Earth probably into Inferior Oolite. Depth 194 feet. 3,000 gallons per hour.

Shaft No. 4, south-west of Lyegrove Farm, through Fuller's Earth into Inferior Oolite. Depth 224 feet. 1,000 gallons per hour.

Shaft No. 5, east of Plough Farm, near the Cross Hands, through Fuller's Earth and Inferior Oolite. Depth 263 feet. 2,000 gallons per hour.

Shaft No. 6, west of Plough Farm, through Inferior Oolite and Cephalopoda-bed into Cotteswold Sands. Depth 281 feet. 10,000 gallons per hour.

Shaft No. 7, Old Sodbury. Through Middle Lias into Lower Lias clay. 200 gallons per hour.

The Cephalopoda-bed, portions of which were brought up from the shafts near the Cross Hands, was richly fossiliferous, and it presented its characteristic iron-shot character. Two

samples were examined by DR. W. POLLARD and found to contain in one instance 15·88 per cent. of metallic iron and 29·8 of silica, and in the other sample 17·96 of iron and 7·9 of silica.

Ammonites bifrons var. *hildensis*, and *A. striatulus* were obtained from the lower strata in Shaft No. 6.

On the slopes west of Shaft No. 6 the sandy loams of the Middle Lias were exposed. A brickyard north-west of the Village Farm showed stiff grey Lower Lias clays with some poorly preserved *Ammonites*, *Belemnites penicillatus*, and also a large specimen of *Inoceramus ventricosus* (undulated variety). The clays probably belong to the zone of *Ammonites Jamesoni*.

From this point onwards to Patchway the cuttings were visited a second time by MR. WOODWARD, and on this occasion in company with MR. STRAHAN. (Messrs. Woodward and Strahan)

South of Colts Grove a cutting showed a slightly fractured anticline in the dark shales and clays, with a few thin bands of limestone and nodules belonging to the zone of *Ammonites semicostatus*. *Gryphæa arcuata* occurred here and some septaria, but with the exception of *A. semicostatus* few fossils were to be seen. The strata have but a very gentle dip eastwards.

South-east of Chipping Sodbury the cutting (18 feet deep in places, but about to be considerably deepened) showed beneath the clays with *A. semicostatus*, about ten feet of rubbly limestones belonging to the zone of *Ammonites Bucklandi*, and yielding *Ammonites Conybearei*, *Lima gigantea* (abundant), and *Gryphæa arcuata* (rare). The beds dip eastwards at 4° and rest on clays with occasional limestone-bands, the basement portion of which comprises several bands with *Ostrea liassica*, *Pleuromya*, etc., representing the Ostrea-beds of the zone of *Ammonites planorbis*.

The strata have been thrown into gentle undulations. The general section of the strata is as follows:—

		Ft.	*in.*
Lower Lias.	Ostrea-beds.		
Rhætic Beds	Pale grey compact and shelly limestone, with small *Lima*, *Modiola*, and other bivalves	1	6
	Brown and grey clay	0	4
	Cotham stone	0	2 to 0 5
	Grey highly calcareous marls and marly limestones seen to depth of	12	0
	Black shales with *Avicula contorta*, *Cardium rhæticum*, and *Modiola*.		

Close to Lilliput Farm a thick mass of hard Carboniferous quartz-grit with occasional pebbles was found to project at the base of the railway with the black (Rhætic) shales banked against it and overspreading it. The grit dips westwards at an angle of about 40°. West of the road by Lilliput Farm the Carboniferous Limestone, with the same dip, has been deeply excavated. It includes bands of shale and thick beds of grit

like that just mentioned, and which could not have been distinguished from Millstone Grit but for the fact that they are interbedded with a dark oolitic limestone and overlain by massive light-coloured limestone.*

These Carboniferous Rocks form the top of a crag which has been buried in Triassic sediments and subsequently revealed by denudation. The continuation of the cutting exhibits the banking of the marls against the steep westward face of the crag, and just suffices to show the top of the red marls terminating against the rising slope and overlapped by some friable buff-coloured dolomite associated with green marls, and evidently belonging to the Tea-green series. Large loose blocks of Carboniferous Limestone appeared to be incorporated with the marls, but the absence of any beach-deposit or of any water-worn material was particularly noticeable in these Triassic marginal deposits. A partial analysis of the buff-coloured dolomites by DR. POLLARD yields the following result:—

Earthy limestone, partially dolomitised, G.W.R., near Chipping Sodbury.

Part insoluble in hot dilute HCl	19·5
CaO	27·7
MgO	11·4
FeO	1·6
Fe_2O_3	2·1
Al_2O_3	1·0
(CO_2 calculated on CaO, MgO, and FeO	35·7)
P_2O_5	trace
	99·0

Westwards a good section of Rhætic and Keuper Beds was to be seen, comprising 25 feet or more of the strata, as follows:—

White decomposed marl with *Modiola minima*, and with hard decomposed limestone in one or two bands.	
Grey clay	4 to 5 feet.
Pale grey and whitish marl, reddish-brown in places, having an irregular and almost nodular appearance when seen from a distance	9 feet.
Black shale with pyrites, *Cardium rhæticum* / Thin sandstone, about ½ inch	about 10 feet.
Grey and tea-green marls—with calcareous gritty bands in places	about 8 feet.
Red and variegated marls (Keuper).	

The Tea-green marls were exposed in the valley S.S.E. of Raysfield Farm and again by the orchard and plantation N.N.W. of Chescombe Farm. The green marls fall to pieces readily in water, and after decantation leave a residue of minute crystals of calcite. The same fact has been noticed by MR. STRAHAN in green

* Similar beds noted as "firestone" were observed in the Carboniferous Limestone near Tytherington by the REV. H. H. WINWOOD. *Proc. Cotteswold Club*, 1889.

marls of this age in Glamorganshire, where, however, the crystals ranged up to half an inch in length and were so abundant as to form a heap after the removal of a lump of marl by rain. (Messrs. Woodward and Strahan.)

North-west of Wapley Common, both in the main-line and in a loop-line connecting with the Midland Railway, the red marls contained crystalline patches of celestine which occupied pockets of the red and variegated marls, but manifested no connection with the green tinges in the marls. The crystals were mostly small, none approaching in size those found near Wickwar.

South of Coalpit Heath the highest Coal-measures of the Coal-field are cut through; these comprise red, yellow, and purple shales with a few thin gritty bands dipping eastwards at about 25°. Overlying these is a stiff yellowish clay-soil three feet thick. Below the level of these strata in the ground to the west the railway passes through a tract where there have been many trials for coal, and some old coal-pits. Sandy shales were seen by the wood south of Blackberry Farm.

West of the Frome river at Huckford there is an old quarry in the Pennant Grit, and further west the rock has been exposed in a deep cutting which extends to the north of Prospect House, Winterbourne. The Pennant Grit here consists of thick and thin bedded sandstone, false-bedded and dipping eastward. It contains some irregular coaly seams together with an occasional large spherical dogger, and is much stained by iron-oxide, presumably from New Red rocks which formerly rested upon the strata. Towards the higher ground the beds are flaggy and much broken up, and the rubble is in places bent so as to exhibit "terminal curvature." The Pennant Grit, shown in the deep road-cutting, rests on mottled clays with veins of calcite. These clays bear some resemblance to Keuper Marls. Near the junction the Pennant Grit shows signs of fracture and slight displacement, due probably to land-slipping.

On the east side of the Bradley Brook three or four feet of red (alluvial) earth were seen over the Pennant Grit. Passing towards Stoke Gifford to the south-west of Mulgrove Farm a deep cutting has been excavated in red (Keuper) marls, with apparently impersistent bands of hard coarse-grained sandstone and blue marl with drusy cavities containing celestine.

These beds dip westwards, showing signs of slight displacement at one point, and are overlain by red and variegated marls and finally by 10 feet of grey marls at the base of the Rhætic series. These beds of grey marl contain in places impersistent layers and nodular masses of marly sandstone. The junction with the overlying Black Shales is sharp. Frequently there occurs a thin sandy layer at the junction. In some places the dark shale was seen to rest directly on the green marl, with a sharp plane of division, and in others there was evidence of slight disarrangement of the marl and of the incorporation of it with the black shale, but this was within the thickness of about one inch.

A good general section of the Rhætic Beds and basement-beds of the Lower Lias is continued westwards, interrupted by one or two faults which traverse the ground from N.E. to S.W. to the

Messrs. Woodward and Strahan.) S.S.E. of Stoke Gifford. The series of strata there exposed may be tabulated as follows:—

		Ft.	in.
Lower Lias.	Ostrea-beds.		
Rhætic Beds and Keuper Marls	Bands of pale compact limestone, showing false-bedding and clay with impersistent bands and nodules of Cotham Stone	3	0
	Rusty band	0	3 to 0 4
	Shaly marls with thin impersistent rusty bands	1	2
	Pale shaly marl passing into thin-bedded White Lias here and there	3	6
	Black shales—rusty where exposed	1	6
	Dark grey earthy limestone	0	1 to 0 3
	Grey and brown rusty clays and shales, with a few lenticular nodules of hard limestone	10	0
	Thin sandy layer ½ in. seen in places.		
	Tea-green, grey, and yellow rusty marls	10	0
	Red and variegated marls.		

The Black shales at the surface become a stiff brown clay. The ground in places was found to be cracked down to the junction with the Tea-green and grey marls, a depth of about ten feet. At the western end of the cutting traces were observed of the Lower Lias limestones with *Unicardium cardioides*, &c.

West of the road and S.W. of St. Michael's Church, Stoke Gifford, the excavation for a new road bordering the railway showed the following section:—

		Ft.	in.
	Clay soil with bits of White Lias	1	0
Rhætic	Marl and thin white limestone	2	0
	Grey clay and stone with Cotham Marble	1	0
	Brown and grey clay and rusty bands	1	0
	Dark grey clay	1	6
	Grey marly beds.		

The upper layers here were somewhat displaced by soil-movements on the sloping ground. In some examples of the Cotham or Landscape Marble the weathered surfaces showed the arborescent markings in relief.*

Mr. Reid.) *Railway from North Walsham to Mundesley, Norfolk.*—This new line was examined by MR. CLEMENT REID last spring. It is carried at so high a level that the shallow cuttings only expose sandy gravels, forming the upper part of the Glacial Deposits. These gravels, as a comparison of the cliffs with the inland sections in the Cromer railway had led us to expect, are little disturbed or contorted; in fact the only marked contortions were seen in the cutting between North Walsham and the Canal.

---

* *See* H. B. Woodward, *Geol. Mag.* 1899, p. 78.

II.—PETROGRAPHICAL WORK.

Much of the petrographical investigation carried on during the past year by the Geological Survey has been embodied in the foregoing account of the field-work of the staff. Some statistics may here be given, and thereafter a reference to some of the other results of the microscopical and chemical examinations may be added.

(Mr. Teall.) The number of specimens of rocks of which thin slides were prepared and microscopically examined and reported on by Mr. Teall was 369. They were collected partly in Devon and Somerset, but chiefly in the Highlands of Scotland. Thin slices of English and Scottish rocks to the number of 642 have been prepared during the year and added to the collection at Jermyn Street. The number of rock-specimens gathered by the collectors in Scotland amounted to 849 in illustration of the geology of the counties of Argyll, Inverness, Ross and Cromarty, Lanark, Ayr, Peebles and Midlothian. Of these no fewer than 666 were procured in Skye for the purpose of furnishing materials for the detailed study of the petrography of that interesting and complicated island. In the Irish branch of the Survey 162 thin slides of Irish rocks were prepared last year, and reports upon these have been furnished by Mr. Seymour.

The total number of thin slices of English and Welsh rocks now in the collection of the Survey in Jermyn Street is 3193; of Scottish rocks 8293, or together 11,486. The number of Irish slides in the Dublin Office is 2181.

Among the more important petrographical results of the work of the Survey in 1898 special mention may be made of the remarkable aegerine-granulites discovered by Mr. Cunningham-Craig near Derry Lodge, Braemar. These have been studied by Mr. Teall who finds them to be new to Scotland, and so far as he is aware they have hitherto been unknown in any areas of Archæan crystalline schists. Their mineralogical composition suggests affinities with igneous rocks of the nepheline-syenite group such as those occurring in Sutherland (borolanites) and in the Christiania district.

In the Explanation to Sheet 75 and in the *Annual Report* of the Geological Survey for 1896, attention was directed to the occurrence of cordierite-bearing rocks in the Eastern Highlands; and the apparent absence of corundum, a mineral which might naturally be expected to occur in these rocks, was commented upon. This mineral has now been found by Mr. Teall in similar rocks from the Western Highlands near the Ben Cruachan mass of granite (*ante* p. 87). It was not detected in the thin sections, but in the residue left after treating the rock with hydrofluoric acid. If the similar rocks from the Eastern Highlands be treated in the same way, it is highly probable that corundum will be found in them also.

(Mr. Teall.) Corundum is known to be formed in two ways;—(1) as a product of the crystallization of igneous magmas, and (2) as a metamorphic mineral in contact-rocks. Illustrations of both these modes of formation are now known to occur in Great Britain. The case described by PROF. BUSZ ot the occurrence of minute crystals of corundum in a felsite from South Brent is an example of the first, and the rock from the neighbourhood of Ben Cruachan, discovered by MR. KYNASTON, is an example of the second.

In addition to the ordinary routine work of the petrographical department, a series of microscopic slides of rocks from British Guiana, sent over by PROF. J. B. HARRISON, Government Analyst, has been examined and reported upon by MR. TEALL. The results have been published by the Government of the Colony in a Report on the Geology of the North-west District. In a letter recently received from PROF. HARRISON, it is announced that certain conclusions, suggested by an examination of the microscopic slides, as to the field-relations of some of the rocks, have since been confirmed.

In the last *Annual Summary* reference was made to the work done on specimens sent home by the JACKSON-HARMSWORTH polar expedition. A further series of rocks and fossils brought home by the expedition has been examined, and the results have been published by the Geological Society of London in a joint paper by MR. E. T. NEWTON and MR. TEALL.

Many enquiries relating to practical and scientific matters have been addressed to the petrographical department during the year and, in all cases, such information as was possible has been freely given.

In order to increase the value, for purposes of reference, of the large series of English and Scottish rocks now under MR. TEALL'S charge, a card catalogue has been prepared by MR. RHODES.

Much assistance has been obtained during the past year from chemical analysis in the determination of rocks, and in obtaining information regarding certain problems which the field-observations could not explain. MR. GRANT WILSON in Edinburgh has completed the analyses of 17 rocks from the Highlands. Most of these analyses have been embodied in previous pages of this *Summary*.

The need of more continuous chemical aid has pressed for some years upon the attention of the DIRECTOR GENERAL, and means were adopted by him last year to remedy this deficiency in the staff. Advantage was taken of a vacancy in the establishment to secure the services of an accomplished chemist, DR. POLLARD, who since his appointment has been uninterruptedly employed in the laboratory at Jermyn Street. The most interesting and important of his investigations has consisted in the detailed analyses of a series of Cambrian dolomites from Durness in Sutherland and the Isle of Skye. Other examinations which may be alluded to were that of a white clay from a boring at Leslie in Fifeshire, a nodule in Limestone from Glenelg, and a

specimen from a boring at Brabourne. An account of these investigations is given below. Several other analyses (for the most part partial) have been made, as well as the qualitative examination of several rocks and minerals for petrographical purposes, or the identification of minerals for museum specimens.

Cambrian Dolomites from Durness and Skye.—Some questions of great interest having arisen both in the field-work and in the preparation of the descriptive memoir on the North-west Highlands, with regard to the dolomitization of the Cambrian limestones of that region, it was determined to subject some of the rocks to careful chemical analysis by DR. POLLARD. (Dr. Pollard.

The specific gravity of a series of specimens from Durness sent up for examination was first determined. As is seen from the following list the majority range between 2·80 and 2·86. That of Calcite is 2·72 and Dolomite 2·85–2·95 (Rosenbusch-Iddings).

List of specimens sliced and analysed :—

	Sp. gr.
No. 8129. Quarry, 150 yards E. of Sango Bay, Durness	2·84
8130. Eilean Hoan, 2½ miles E. of Durness	2·85
8131. Eilean Dubh Group, Eilean Hoan	2·82
8132. Dolomitic Limestone in Fucoid shales, near Grindaidh, Kyle of Durness	2·81
8133. Big Croisiphuill (coarse, crystalline part)	2·78
" " (compact part, *see* analysis)	2·67
8283. Eilean Dubh Group, A'Ghoil Sgein, near Eilean Hoan	2·85

The following were neither sliced nor analysed :—

Eilean Dubh, Durness	2·85
Eilean Dubh Group, Sailmhor	2·83
Base of Mottled Group, Sailmhor	2·85
Eilean Dubh	2·86[Max.]
Mottled Limestone, Eilean Hoan	2·84
Dolomitic Limestone, Eilean Hoan, 2½ miles E. of Durness	2·83
Middle of Mottled Group, E. of Sailmhor	2·85
Flaggy beds, middle of Eilean Dubh Group, nr. Sailmhor	2·82
Dolomite above chert, base of Sangomhor Group	2·81
Near top of Mottled Group, Sailmhor	2·84
Limestone Skerry, Balnacuile Bay	2·82
Overlying Chert-bed, Sangomhor	2·84
" " " "	2·84
Thin band of Dolomite in Big Croisiphuill, E. side of Lake Borrolaidh	2·84
About middle of Mottled Group, Sailmhor	2·84
Roadside, 250 yards E. of Sangomhor	2·83
Top of Eilean Dubh, Sailmhor	2·86[Max.]
Limestone Skerry, Bailnacuile Bay	2·85
" " " "	2·80
" " " "	2·85
" " " "	2·84
" " " "	2·73[Min.]
" " " "	2·82
" " " "	2.84
Salterella-Limestone, Gruidaidh group	2·85

From the specific gravity determinations it seems most probable that the specimens (with one or two exceptions)

r. Pollard.) are Dolomites. The analysis of these Dolomites gave the following results:—

No.	8129	8130	8131	8132	8283	8063	8064
Sp. gr.	2·84	2·85	2·82	2·81	2·85	2·85	2·86
Part insol. in dilute Hydrochloric acid	1·83	2·42	15·81	28·96	2·01	2·26	1·72
SiO_2	·16	·11	·29	·49	trace	·50	
FeO	·21	·34	·32	1·52	·35	·45	·34
Fe_2O_3		·28	·36	·29	·10		
Al_2O_3				·50			
P_2O_5	(trace?)	trace	·05	·62	trace		
MnO	·17	·24	·19	·33	trace	·22	·19
CaO	29·65	30·05	25·40	21·73	30·09	30·50	30·53
MgO	21·53	20·25	18·24	13·61	20·83	21·19	20·81
CO_2	46·62	46·15	39·65	31·45	46·59	44·54	46·25
Water	—	—	—	·79	·28	—	—
TOTAL	100·17	99·84	100·31	100·29	100·25	99·66	99·84

Nos. 8063 and 8064 are specimens from Strath, Skye, sent up for analysis by MR. HARKER. The amount of insoluble residue in No. 8132 varies considerably in different parts of the specimen. The sample for analysis was prepared from chips from different parts of the hand-specimen.

Ratio of Lime to Magnesia and Carbon dioxide in the above specimens:—

	CaO	:	MgO	:	CO_2
8129	1·0	-	1·02	-	2
8130	1·06	-	1	-	2·07
8131	1	-	1	-	1·99
8132	1·14	-	1	-	2·10
8283	1·03	-	1	-	2·03
8063	1·03	-	1	-	1·91
8064	1·05	-	1	-	2·02

The mottled Dolomite (No. 8129) contains small black inclusions, which occur most frequently in the dark patches. (This is clearly seen in the thin slice.) The part insoluble in dilute hydrochloric acid is blackish, owing to these minute specks. These were shown to be carbon, and an approximate determination (loss on ignition of residue after drying at 150°) gave ·06%. (The true amount may be even less owing to the possibility of part of the loss being due to water.)

Microscopic Examination of Slices 8129—8132 *and* 8283.

[8129] Crystals of carbonate, mostly with irregular outlines from ·1 to ·3mm. diameter. Occasional small veins of Limonite. The mottling seems to be due to very minute black grains included in many of the crystals. The crystals which outline the dark patches in the rock appear to contain more of these black inclusions.

[8130] Crystals of carbonate, mostly with irregular outlines, from ·08 to ·2mm. diam. Occasional grains and veins of Limonite, some very minute black grains as inclusions, less frequent than in 8129.

[8131] Crystals of carbonate with irregular outlines, from ·005 to ·003mm. diam., and occasional quartz grains of about the same size. Small patches and veins of Limonite.

[8132] Impure carbonate rock with Limonite, rounded grains of quartz and a pleochroic mineral, possibly hornblende. The carbonate crystals vary considerably in diameter (from ·05 to ·6mm.). The rock is obviously of organic origin. It contains numerous fragments of organisms, some, referred by Mr. E. T. NEWTON to the sponge-like forms *Archæocyathus*, *Calathium*, &c., and others are pieces of Molluscan shells.

[8283] Crystals of carbonate with more or less irregular outlines. Occasional veins of Limonite, small carbonate crystals, and short veins of microcrystalline quartz. On the slice there is one patch of carbonate crystals, larger than the main mass, with V-shaped markings of Limonite, probably formed by the decomposition of siderite crystals.

[8133] The hand specimen of "Big Croisiphuill" consists of bands of crystalline carbonate, and a compact mass of carbonate and cryptocrystalline silica.

The slice shows bands of crystalline carbonate (crystals from ·1 to ·2mm. (diam.) with some Limonite, and cryptocrystalline silica containing carbonate crystals from ·1 to ·2mm. diam. There are minute black grains (carbon ?) in the carbonate bands.

The compact part was separated as cleanly as possible from the crystalline part, and each analysed. The results are :—

[8133]	Crystalline Part	Compact Part
Sp.Gr. - - -	2·78	2·67
Part insol. in dil. HCl	1·73	56·01
SiO_2 - - -	0·13	0·22
FeO - - -	0·16	} 0·27
Fe_2O_3 } Al_2O_3 } - -	0·13	
MnO - - -	0·25	trace
CaO - - -	32·54	22·43
MgO - - -	19·06	1·40
CO_2 - - -	45·82	19·24
Water - - -		0·31
Total	99·82	99·88

Ratio of CaO : MgO : CO_2 in crystalline part = 1·16 : 1 : 2·09. The residue of the compact part consists of 99·2 per cent. Silica.

A partial analysis was made of the specimen from the "Limestone Skerry from Bailnacuile Bay," sp. gr. 2·73. (Next lowest sp. gr. in the series is 2·80). This is seen to be a partially dolomitized rock, with a considerable amount of residue :—

Residue	19·9
$Fe_2O_3Al_2O_3$	1·6
MgO	4·4
CaO	38·0

Attention should be drawn to a number of analyses of Sutherland limestones by DR. ANDERSON,* who analysed specimens from the following localities:—Knockdon, Elfine, Duirness, Eribol, Achmore, Stronchrubie, Kirktown, and Ledbeg. All these are practically true Dolomites, excepting Duirness, and the "white crystalline" from Ledbeg. Several other analyses are given by PROFESSOR HEDDLE (*Min. Mag.* iv. 239), who also quotes DR. ANDERSON'S analyses.

As it seemed just possible (though improbable) that these rocks might be a mixture of calcite and magnesite, or of calcite, magnesite, and dolomite, the ratio of Ca to Mg dissolved by water saturated with carbonic acid was determined. The specimens on which this was tried were 8129 and 8064. In both cases the ratio was practically 1 : 1. Had they been mixtures far more CaO than MgO would have been dissolved.

Similar results were obtained (with 8064) by the action of 1 per cent. HCl on the rock powder for varying lengths of time (15 to 40 minutes) at ordinary temperatures.

From the results here presented it is seen that, with one or two exceptions, the specimens are Dolomites and not Limestones.

A remarkable group of limestones appears among the crystalline schists of Loch Duich and Glenelg, Inverness-shire. A nodule from the Glenelg Limestone, sent up by MR. CLOUGH, was sliced and examined by MR. TEALL, who suggested that the minerals should be separated and analysed by DR. POLLARD. The following is a short account of the results of the microscopical and chemical examination of this nodule:—

[7923] Nodule in Limestone ⅔ miles+40 yards E. of Sgiath Bheinn, Glenelg. This nodule consists mainly of a mineral of the Olivine group, mostly quite fresh, and of an isotropic mineral of high refractive index embedded in an aggregate of grains of the former.

The minerals were separated by methylene iodide, and analysed. The Olivine mineral proved to be Försterite, and the isotropic mineral Spinel. In addition to the Spinel and Försterite there are also Calcite and Diopside, but not in great quantity.

In a boring for water at Leven Bank paper-mill, Leslie, Fife, under a sheet of intrusive dolerite about 50 feet thick, a "light fireclay" was pierced. This deposit, 27 feet and a half in thickness, rested upon soft white Lower Carboniferous sandstone, and possessed such a peculiarly greasy feel that a specimen of it was sent to the Geological Survey for examination. An analysis of it by DR. POLLARD gave the composition shown in the subjoined table:—

SiO_2	49·05
Al_2O_3	33·52
CaO	·64
MgO	·72
K_2O	4·90
Na_2O	·20
Water at 105°	5·45
Water above 105°	5·90
	100·38

* *Report of the Highland and Agricultural Society*, 1851-53, p. 273.

The peculiar greasiness to the touch at first suggested that this clay might be magnesian and might possibly be a decomposed product of some of the volcanic rocks of the Lower Carboniferous series. But the trifling proportion of magnesia in its composition shows that the peculiarity must be due to some other cause.

III.—PALÆONTOLOGICAL WORK.

The Palæontological Department at Jermyn Street continues not only to take charge of all the palæontological work required in the Museum of Practical Geology, but also examines and determines all fossils collected by the Geological Survey in England, Wales, and Ireland. The palæontological work of the Scottish branch is carried on at Edinburgh.

(Mr. E. T. Newton.)

Among the various investigations in which the palæontologists at Jermyn Street, under the superintendence of MR. E. T. NEWTON, F.R.S., have been engaged during the past year, reference may be made to that connected with certain jaws, vertebræ, and other bones of a fish which were found by MR. CLEMENT REID some years ago in the Bembridge Marls of Hamstead, Isle of Wight, and which have been awaiting more material for their elucidation. This additional evidence has now been supplied by further specimens obtained by MR. G. W. COLENUTT in the Bembridge and Osborne Beds, near King's Quay, Ryde. All the specimens have been studied by MR NEWTON himself, who refers them to the living ganoid genus *Amia* and proposes the name of *Amia anglica* for MR. REID'S specimen and for one of those found by MR. COLENUTT in the Osborne Beds of King's Quay, which is likewise represented by several parts of the skeleton. Many of the isolated jaws in MR. COLENUTT'S collection from these beds are believed to belong to the same species. A single slender maxilla also from the Osborne Beds and apparently belonging to the same genus, is referred to another species, to be called *A. Colenutti*. The close relationship of these forms to certain fish remains described by COPE, LEIDY, and MARSH from Tertiary rocks of North America, as well as the distribution of the closely allied forms both in North America and in Europe, are alluded to in a paper published by the Geological Society.

A block of sandstone obtained by MR. JOHN DAVID, of Porthcawl, Glamorganshire, from a quarry in Penarth Beds, at Stormy Down, near Bridgend, was found to contain the impression of a large reptilian jaw. The interest of the discovery was at once apparent to MR. R. H. TIDDEMAN, at whose request MR. DAVID very generously presented the specimen to the Museum of Practical Geology. The fossil, like so many of the well-known reptilian remains from the Elgin Sandstone, is merely a mould in the rock, the bone having disappeared. MR. NEWTON undertook the working out of the specimen, and having prepared casts in gutta percha, describes it as a left dentary bone of a megalosauroid reptile, with the dentition very perfectly represented

Mr. E. T. Newton.) The teeth are lodged in deep sockets, the larger ones being recurved, flattened from side to side, and serrated; the serrations on the posterior concave border extend from the point to very near the margin of the jaw, while those of the anterior convex border occupy only about two-thirds of the apical portion; in all the teeth this proportion is maintained. The presence of successional teeth in some of the alveoli, and of the points of others in some of the pits seen at the bases of the larger teeth, clearly show the mode of succession to be of the well-known type, where the germ of the new tooth appears on the inner side of the fully-developed tooth, and pressing upon the fang causes its absorption. The new tooth enlarging comes to occupy the interior of the fang of the old one, which by the continued absorption of its base falls out, or is easily broken off, when the new tooth is found occupying the middle of the alveolus, and subsequently comes to occupy the place of its predecessor. The genus *Zanclodon* (including *Teratosaurus*) is believed to be the most nearly allied fossil to this Bridgend specimen, and as it cannot be definitely referred to any known species it is named *Zanclodon cambrensis*. A full account of the fossil has appeared in the *Quarterly Journal of the Geological Society* (vol. liv., p. 646).

In a previous part of this *Summary* (p. 58) reference was made to the assistance derived by the field-surveyors in Ireland from the reports supplied to them by the palæontologists at Jermyn Street regarding the fossils collected from Silurian rocks. During the past year no fewer than ten different consignments of fossils have been sent from different Irish counties to the Museum of Practical Geology for determination. Although the specimens have for the most part been in a poor state of preservation, yet some good results have been obtained, which have much assisted the progress of the field-work. Early in the year a series of specimens from places in Wexford and Wicklow was examined and found to indicate Lower Silurian rocks, perhaps as low as the Arenig group. One set from near Arklow included specimens much resembling *Protovirgularia*, and hence seemed to indicate Upper Silurian rocks in that neighbourhood, but the identity of the organisms could not be established. A second series of specimens obtained from the same localities gave similar negative results.

Another series received from places near Arklow, Enniscorthy, and Courtown Harbour proved exceptionally interesting. From each of these places *Caryocaris Wrighti* was obtained together with *Didymograptus*, *Phyllograptus*, *Dicellograptus* and *Cœnograptus*, leaving little doubt as to the Arenig age of the strata. A fourth series from Bray Head included examples of *Oldhamia*, but nothing else that might indicate the horizon of the rocks.

Two series of graptolites received from various places in Tipperary, were better preserved, and represented such forms as *Monograptus priodon*, *M. Flemingi*, &c. They thus showed the

rocks to be Upper Silurian, and probably of Tarannon or Wenlock age, some apparently high in the Wenlock series. (Mr. E. T. Newton.)

The examination of a selected series of graptolites from fifty-two localities south of Belfast confirmed the presence of strata of Llandeilo, Bala, Llandovery, Tarannon, and perhaps even of Wenlock age.

Late in the year a further collection was received from Tipperary which proved to consist almost wholly of *Monograptus riccartonensis*, thus indicating beds of Tarannon or Wenlock age. With these graptolites came a number of specimens from localities in Sheets 156 and 167, where the strata are much cleaved (*ante* p. 61.) These specimens are deserving of notice, although it is by no means certain that they are of organic origin. Many of them have the appearance of large graptolites, and one or two of the more distinct examples have so close a resemblance to a large-sized Monograptid, that if found alone they would almost certainly be regarded as such; and, indeed, it would be unwise to say positively that they are not graptolites much altered by pressure and cleavage. When, however, the whole series is examined, there is found to be a gradual change from these more clearly defined forms to others in which it is quite evident that the serrations are due to cross fractures and interruptions of the lines of cleavage. No one would be bold enough to assert that the latter specimens are graptolites, although it is possible they may be such, but almost destroyed by pressure and cleavage, while the more distinct forms first mentioned may be less altered specimens. On the other hand, it seems quite possible that even the most clearly defined forms may be altogether due to cleavage. One or two of these pseudo-graptolites are bent at an angle, and the portion which crosses the cleavage marks is serrated, while the part running parallel with the cleavage lines has no serrations. Some at least of these pseudo-graptolites are found on the cleavage planes, and not on the bedding, and the same may be said of certain fucoid-like markings found in the same slates.

In determining the graptolites MR. NEWTON has from time to time received valuable assistance from Professor Lapworth, who has always been ready to give the Survey the benefit of his long experience among these organisms.

Allusion was made in the *Summary of Progress* for 1897 to a further series of rocks and fossils brought back from Franz Josef Land by the Jackson-Harmsworth Polar Expedition, on the return of the party in the autumn of 1897. The examination of these specimens by MR. NEWTON and MR. TEALL has confirmed the conclusion arrived at from the study of the collection previously received. Some additional facts, however, were deemed worthy of being placed on record, and these have been embodied in a paper, "Additional Notes on the Rocks and Fossils from Franz Josef Land" (*Quart. Journ. Geol. Soc.*, vol. 54, 1898, p. 646). It was fully expected that a personal consultation with DR. KOETTLITZ, the geologist of the expedition, would necessitate some alterations of the altitudes given in the first paper (1897), and a

[r. E. T. ewton.)

few such alterations have been made, but fortunately they do not in any way alter the relative positions of the rocks. In view of the wide distribution of the common type of basalt, an analysis of it has been made and compared with analyses of two rocks from Iceland given by Bunsen, and the similarity is striking.

The widespread evidence of silicification in Franz Josef Land naturally suggests that siliceous springs may have existed there in times past, as they do at the present day in Iceland.

Further specimens of Radiolarian Chert have been obtained, but now as pebbles in a calcareous sandstone of Jurassic age, and are probably, as previously suggested by DR. G. J. HINDE, derived from rocks of Palæozoic age. Plant-beds similar to that already described on the north side of Cape Flora at a height of 700 feet above the sea, have been met with at other places around the Cape, and, although the plant-remains seem less abundant at the new localities, there is a similar assemblage of pine-needles, fern pinnules and Ginkgo leaves. It is tolerably evident, therefore, that this Upper Jurassic plant-bed extends over a large area at approximately the same level. At one place, it is true, a similar bed occurs at 900 feet, but this difference is probably due to the interpolation of the sheets of basalt. Another point of interest is the discovery of a fragment of *Ammonites Lamberti* in close relation with the base of the basalt and apparently about 50 feet above the horizon from which *Am. Tchefkini* was obtained, thus indicating the presence of Oxford Clay.

The bed at Windy Gully, east of Cape Flora, which yielded *Am. Ishmæ* is now said to be about 400 feet above the sea (not 300 as before stated). Additional specimens of the last named species have been found, together with a Belemnite and parts of a large Inoceramus-like shell, the undulated surface of which reminds one of the Cretaceous *Inoceramus Cuvieri*.

From the locality 500 yards west of Elmwood additional and better preserved examples of the large *Avicula* have been found.

The carbonised and recent-looking vegetable remains from Cape Richthofen, which it was thought might perhaps be from Tertiary beds, have been submitted to DR. NATHORST, who thinks the absence of any fragment of a dicotyledon militates against their being of Tertiary age, and leads him to think that they may after all belong to the Jurassic rocks.

The large collection of British fossils now gathered together and displayed in the Museum of Practical Geology continues to be largely made use of by palæontologists, and specimens from it are frequently figured in illustration of their investigations. Thus in the course of the past year MR. A. BELL, in his paper "On the Pliocene Beds of St. Erth" (*Trans. R. Geol. Soc., Cornwall*, vol. 12, part iii. 1898), has figured *Columbella erythrostoma*, Bon., *Kellia corbuloides*, Phil., *Littorina gibbosa*, E. and B., and *Odostomia magna*, E. and B. MR. G. C. CRICK, in his memoir "On the Muscular Attachment of the Animal to its Shell in Some Fossil Cephalopoda" (*Trans. Linn. Soc.*, vol. 7, p. 4, 1898), has figured *Turrilites tuberculatus*, Bosc., and *T. Mantelli*,

Sharpe, from the Lower Chalk, while MISS J. DONALD, in her paper on Carboniferous Gasteropoda (*Quart. Journ. Geol. Soc.*, vol. 54, pl. v. fig. 5, 1898), has given a figure of *Rhabdospira compacta*, Donald, from the Yoredale Rocks of Wensleydale. MR. CLEMENT REID has figured *Limnocarpus* from the Tertiary Deposits of Hampshire. (*Proc. Linn. Soc.*, Botany, vol. xxxiii., p. 464). (Mr. E. T. Newton.)

Besides these a considerable number of the Jermyn Street specimens have been figured in the monographs of the Palæontographical Society for 1898, as shown in the subjoined list, which is here given in full, as it contains the names of what have now become type specimens.

Specimens figured by PROF. T. RUPERT JONES and DR. H. WOODWARD in their "Palæozoic Phyllopoda":—

Dithyrocaris testudinea, Scoul.
„ *Colei*, Portl. Six specimens.
„ *orbicularis*, Portl.

Specimens figured by the REV. G. F. WHIDBORNE, M.A., in his "Devonian Fauna of the South of England":—

Chonetes margaritacea, Whid.
Discina nitida, Ph.
Lepidesthes? devonicans. Three specimens
Protocidaris acuaria, Whid. Two specimens.
Palæaster longimanus, Whid. Three specimens.
Protaster granifer, Whid. Two specimens.
Eugaster? perarmatus, Whid.
Protaster? scabrosus, Whid. Three specimens.
Ophiurella? gregaria, Whid.
Adelocrinus hystrix, Ph. Two specimens.
Actinocrinus Porteri, Whid. Four specimens.
Rhodocrinus?
Actinocrinus? Batheri, Whid. Two specimens.
Taxocrinus macrodactylus, Ph. Three specimens.
Scaphiocrinus? inordinatus?, Whid.
„ „ *?* sp.
Poteriocrinus. Two specimens.
Scaphiocrinus? plumifer, Whid.

Specimens figured by DR. WHEELTON HIND, B.Sc., F.G.S., in his "British Carboniferous Lamellibranchiata":—

Protoschizodus axiniformis, Portl. Two specimens.
„ „ var. *depressus*, Portl. Two specimens.
Cardiomorpha corrugata, M'Coy.

Scotland. (Mr. B. N. Peach.)

The Palæontological Department of the Geological Survey in Scotland is carried on under the supervision of MR. B. N. PEACH, with the assistance of the Fossil Collectors, MR. A. MACCONOCHIE and MR. D. TAIT. During the past year fossils to the number of 858 have been collected from the Cambrian rocks of Skye, the Upper Silurian rocks of Lanarkshire, Ayrshire, and the Pentland Hills, the Lower Old Red Sandstone and Carboniferous rocks of Lorne and Edinburgh.

It has been the custom of the Acting Palæontologist in Scotland, with the Director General's consent, to distribute certain groups of fossils among specialists for identification and for the publication of descriptions of new forms. Thus the Silurian, Old Red Sandstone, and Carboniferous fishes have been

land. . B. N. sh.)

submitted to DR. TRAQUAIR, who has determined upwards of 800 specimens during the year, and who has furnished the separate notes given on pp. 65 and 72, regarding the forms collected during the past season. About 40 specimens of sponge-like bodies from the Downtonian rocks have been submitted to DR. G. J. HINDE. DR. MALCOLM LAURIE has examined the collection of eurypterids from the Upper Silurian and Lower Old Red Sandstone rocks collected during the last few years, and has been supplied with specimens of some new forms for description. MR. R. KIDSTON has named 13 specimens of fossil plants from the Lower Old Red Sandstone, 209 specimens from the Carboniferous rocks of Arran, a few Lower Old Red Sandstone Plants from Lorne, and a small but interesting collection of 19 specimens of fossil plants from the red sandstones occurring near the Bridge of Awe, referred to on p. 129. MR. J. W. KIRKBY has reported upon a small collection of specimens of *Ostracoda* from the Lower Carboniferous rocks underlying Edinburgh (p. 132). A collection of about 200 Cambrian fossils from Skye and about 20 specimens of graptolites from the Wenlock rocks of the Pentland Hills have been determined by MR. PEACH. Thus in all upwards of 1,200 fossils have been determined during the year. Some of the more important results of the examinations have been embodied in previous pages of this volume.

During the year there have been figured from the Scottish Survey Collection in the Museum of Science and Art, Edinburgh, for the monographs of the Palæontographical Society for 1898 the following specimens:—

By T. RUPERT JONES and DR. H. WOODWARD in their "Palæozoic Phyllopoda":—

Calyptocaris striata, Woodward. One specimen.
Dithyrocaris Colei, Portlock. One specimen.
„ *glabra*, Woodw. and Eth. One specimen.
„ *granulata*, Woodw. and Eth. Two specimens.
„ *lateralis*, M'Coy. Two specimens.
„ *ovalis*, Woodw. and Eth. One specimen.
„ *Scouleri*, M'Coy. One specimen.
„ *tricornis*, Scouler. One specimen.

By DR. WHEELTON HIND in his "British Carboniferous Lamellibranchiata":—

Protoschizodus æquilateralis, M'Coy. Two specimens.
„ *nuculoides*, M'Coy. Two specimens.
„ *obliquus*, M'Coy. Two specimens.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

From the beginning of their existence the Geological Survey and the Museum of Practical Geology have had regard to the industrial and economic applications of Geological Science. Every year the practical usefulness of the data collected by these institutions is becoming more widely recognised, so that a

large part of the time of the resident officers in London, Edinburgh, and Dublin requires to be given to the supplying of information and guidance in matters which involve a knowledge of geology and of the geological structure of the British Isles. Nor are the questions confined to these islands; they frequently relate to the colonies and to foreign countries. Hundreds of applications are made every year by the general public, while the various public departments are constantly requesting advice in similar directions.

During the past year enquiries have been frequent with regard to building-sites, especially in the neighbourhood of London, the publication of the Survey volume on "Soils and Subsoils" having called public attention to the importance of a careful consideration of this subject. A large proportion of the applications have had reference to questions of water-supply, and the maps of the Survey (on the scale of six inches to a mile) are found to be invaluable in such matters, as well as generally in sanitary engineering. These maps are for the most part unpublished, the large scale and the consequent cost of engraving having hitherto prevented their publication. But manuscript copies of them are deposited in each of the three offices of the Survey (London, Edinburgh, and Dublin), for consultation by the public, and they are largely made use of.

Among other subjects in which advice has been sought for, mention may be made of soils in relation to agricultural development; sites for market gardens; situations for cemeteries; routes for light railways; position, extent and quality of building-stones, limestones, road-metal, coal-seams, and coal-mining, metallic ores, peat, and many other stones, rocks, and minerals.

Among the Public Departments which have sought the assistance of the Survey, reference may be made to the Local Government Board, and especially its medical and engineering branches; the Board of Agriculture, the Colonial Office, the War Office, the General Post Office, the Government Laboratory at Demerara, &c. Information has also been given to the Society of Antiquaries in respect to Roman tesserae obtained at Silchester.

V.—MAPS, SECTIONS, MEMOIRS, &c., PUBLISHED DURING 1898.

A.—OFFICIAL.

I.—MAPS.

1.—*England and Wales.*

New Series.—Thirteen sheets of the New Series of one-inch maps have been published during last year, viz.:—

Sheets 36, 45, 56, and 57 in one sheet (= No. 100 Old Series), Isle of Man, by G. W. LAMPLUGH.

Sheet 267, Newbury, by F. J. BENNETT.

Sheet 268, Reading, by J H. BLAKE, with part by F. J. BENNETT.

Sheet 283, Andover, by F. J. BENNETT and C. E. HAWKINS.

Sheet 300, Alresford, by C. E. HAWKINS.

Sheet 328, Dorchester, by C. REID, A. STRAHAN and A. J. JUKES-BROWNE.

Sheet 350, Torquay, by W. A. E. USSHER.

Sheet 355, Kingsbridge, by W. A. E. USSHER.

Sheet 356, Start Point, by W. A. E. USSHER.

Of the above maps, that of the Isle of Man and of Reading are issued in two editions, Drift and Solid; the other maps are only issued with Drift.

Old Series.—Quarter-sheet 46 S.E., Drift Edition, has been published, the survey having been made by W. WHITAKER, A. C. G. CAMERON, and A. J. JUKES-BROWNE. Quarter-sheet 54 N.W., Revised Edition, Solid, has been published with revisions made by W. GIBSON, as notified in the *Summary of Progress* for 1897 (p. 67).

General Map on the Scale of Four Miles to an Inch.—The colour-printed edition of this map has now been completed, Maps Nos. 5 and 14, the two remaining Sheets, having been published during the year.

Six-inch Reference Maps.—102 MS. Coloured Copies of six-inch sheets and quarter-sheets have been made from the field-copies and deposited in the office for public reference. These are as follows:—

Bedfordshire.—33 S.W.
Berkshire.—28.
Brecknockshire.—32 S.E.; 33 S.E., S.W.; 34 S.W.; 38 N.E., S.E.; 39 N.E., N.W., S.E, S.W.; 40 N.W., S.W.; 44 N.E., N.W., S.E., S.W.; 45 N.E, N.W., S.E., S.W.; 46 N.W., S.W.; 49 N.E.; 50 N.E.
Buckinghamshire.—13, 14, 20, 23, 24, 28, 29, 33.
Cornwall.—37 N.E., S.E.; 38 N.W., S.W.; 45 N.W., S.W., N.E., S.E.; 46 N.W., S.W.; 54 N.W., N.E., S.E.; 55 N.W., S.W.
Devonshire.—23 S.E.; 24 S.E., S.W.; 34 N.E; 35 N.W.; 107 N.E, N.W.; 111 N.W., S.E.; 117 N.E., N.W., S.E., S.W.; 119 N.W.
Glamorganshire.—25, 33, 39, 40, 50.
Hampshire.—48, 57, 63, 64, 65, 74, 75.
Isle of Man.—5.
Lancashire.—106 N.E., S.E., N.W., S.W.; 113 N.E., N.W. (Copies made from maps lent by MR. G. H. MORTON, F.G.S.)
Leicestershire.—36 N.E., S.E; 37 S.W., S.E.; 38 S.W.
Middlesex.—11 S.W.; 16 N.W.
Northamptonshire.—40 S.W.; 61 N.W., S.W.
Oxfordshire.—18.
Somersetshire.—9 N.E., S.W., S.E.; 10 N.W., S.W.
Worcestershire.—10 S.W.; 16 N.W.
Wiltshire.—70, 71.

Besides the maps above referred to as published during the past year, the following seven sheets of the one-inch map (New Series) are in the hands of the engravers:—

155, Atherstone and part of Charnwood Forest.
248, Pontypridd in the South Wales Coal-field.
282, Devizes and part of Salisbury Plain.
325, Exeter.
339, Newton Abbot and Teignmouth.
340, Otterton, near Budleigh Salterton.
349, Plymouth and Ivybridge.

Other sheets nearly ready for the engraver are:—

123, Stoke-on-Trent.
187, Huntingdon.
203, Bedford.
220, Leighton Buzzard.
231, Merthyr Tydfil.
261 and 262, Bridgend.
315, Southampton.
316, Havant.

2.—*Scotland.*

Two sheets of the one-inch map of Scotland have been published, viz.:—

19, Argyllshire.
85, Elginshire.

Also revised editions of the following four sheets:—

7, Ayrshire.
40, Fife and Kinross.
57, Forfarshire, &c.
67, Kincardineshire.

Two sheets of the one-inch map are in the hands of the engravers, namely:—

46, Tyndrum and Balquhidder.
55, Blair Athole.

Other maps are nearly ready for the engraver, namely:—

27, North part of Islay.
37, Inverary.
38, Lochs Lomond and Katrine.
86, Huntly.

3.—*Ireland.*

A revised edition of Sheet 29, Carrickfergus, has been published.

Revised editions of Sheets 37 and 38 have been prepared and will shortly be published.

Duplicate copies of the following sheets of the six-inch scale county maps have been prepared and deposited in the Dublin office for public reference:—

Co. Waterford.—Part of Sheet 3.
Wexford.—Sheets 29 and 49.

II.—MEMOIRS.

1.—*England and Wales.*

Six Memoirs have been published during the year, viz.:—

"Summary of Progress of the Geological Survey of the United Kingdom for 1897, with an Introduction regarding the History, Organisation, and Work of the Survey," pp. vii., 176. Price 1s.

"The Geology of the Country around Bournemouth." (Explanation of Sheet 329, New Series.) By CLEMENT REID, pp. iv., 12. Price 4d.

"The Geology of the Country around Eastbourne." (Explanation of Sheet 334, New Series.) By C. REID, pp. iv., 15. Price 6d.
"Supplement to the Geology of the Neighbourhood of Flint, Mold, and Ruthin." (Explanation of Quarter-sheet 79 S.E., Old Series.) By AUBREY STRAHAN, pp. 7. Price 2d.
"The Geology of the Isle of Purbeck and Weymouth." (Explanation of Sheets 341, 342, and 343, New Series.) By A. STRAHAN, pp. xi., 278. Price 10s. 6d.
"The Geology of the Borders of the Wash, including Boston and Hunstanton." (Explanation of Sheet 69, Old Series.) By W. WHITAKER and A. J. JUKES-BROWNE, pp. vi., 147. Price 3s.

Besides the Memoirs which have been published during the year, several others are far advanced or nearly ready:—

In the Press.

"The Water Supply of Sussex from Underground Sources." By W. WHITAKER and C. REID. [Published 1899, Price 3s.]
"The Geology of the Country around Carlisle." (Explanation of Sheets 11, 16, and 17 New Series, 107 Old Series.) By T. V. HOLMES. [Published 1899. Price 1s. 3d.]
"The Cretaceous Rocks of Britain," vol i. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE.

In Preparation.

"The Geology of the Isle of Man." By G. W. LAMPLUGH.
"The Geology of Belford, Holy Island, and the Farne Islands, Northumberland." By W. GUNN.
"The Geology of the Country around Kingsbridge and Salcombe." By W. A. E. USSHER.
"The Geology of the Country around Reading." By J. H. BLAKE.
"The Geology of the Country around Dorchester." By C. REID.
"The Geology of the Country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS, with Notes by W. W. WATTS.
"The Geology of the Country around Newport, Mon." By A. STRAHAN.
"Guide to the Geology of London." Sixth Edition. By W. WHITAKER.

2.—*Scotland.*

No memoir has been issued during the past year, but the first volume of the General Memoir on the Silurian Rocks of Britain which consists of a full detailed account of the Silurian formations of the Southern Uplands of Scotland, is passing through the press, and will be published immediately.

The important Memoir referred to in last *Summary of Progress*, as having been planned for the description of the complicated region of the north-west Highlands has made considerable progress during the past year. It is expected to be ready for the press by the end of the present year.

3.—*Ireland.*

A Memoir on the Soils and Subsoils of Ireland has been prepared in the Dublin Office by MR. KILROE, with the partial assistance of his colleagues, MESSRS. NOLAN, EGAN and MCHENRY. This work when published will, it is hoped, be of considerable service in the cause of Irish agriculture.

B.—Non-Official.

The following is a list of the non-official publications of the members of the staff during the year 1898 :—

Barrow, G.—"On the Occurrence of Chloritoid in Kincardineshire." Quart. Jour. Geol. Soc., vol. liv., pp. 149-156.

Blake, J. H.—"Excursion to Reading." Proc. Geol. Assoc., vol. xv., pp. 304-308.

Cantrill, T. C.—"The Contents of a Carn at Ystradfellte, co. Brecon." *Archæologia Cambrensis*, 5th series, vol. xv., pp. 248-264, July, 1898; also Journ. Anthrop. Inst., August and November, 1898, pp. 3, 4.

Geikie, Sir A.—"Types of Scenery and their Influence on Literature": the Romanes Lecture for 1898. 8vo, London. Summary in *Nature*, vol. lviii., p. 179.

Geikie, Sir A.—"Antarctic Geology." Remarks at Meeting of the Royal Society held on February 24, 1898, to consider the Scientific Advantages of an Antarctic Expedition. Proc. Roy. Soc., vol. lxii., pp. 446-449; and *Nature*, vol. lvii., p. 426.

Geikie, Sir A.—"Science in Education." Address to the Students at Mason University College, Birmingham, October 4, 1898. *Nature*, vol. lix., p. 108.

Goodchild, J. G.—"Obituary Notice of Dr. Heddle." *Mineralogical Magazine*, 1898.

Gunn, W.—"Notes on the Geology of the Isle of Arran." Trans. of the Edinburgh Geological Society, vol. vii., p. 268.

Gunn, W.—"Notes on the Correlation of the Lower Carboniferous Rocks of England and Scotland." Geol. Mag., Dec. IV., vol. v., p. 342.

Harker, Alfred.—"The Natural History of Igneous Rocks. II. Their Forms and Habits." Science Progress (N.S.), vol. ii., pp. 203-218.

Harker, Alfred.—"Norwegian Rhomb-porphyries in the Holderness Boulder-Clays." Proc. Yorks. Geol. Pol. Soc., vol. xiii., pp. 279-280.

Harker, Alfred.—"Petrographical Research among Sedimentary Rocks." Trans. Hull Geol. Soc., vol. iv., pp. 17-20.

Jukes-Browne, A. J.—"On an Outlier of Cenomanian and Turonian [equivalent to Lower and Middle Chalk] near Honiton, with a Note on *Holaster altus*, Ag." Quart. Journ. Geol. Soc., vol. liv., pp. 239-250.

Jukes-Browne, A. J.—"The Delimitation of the Albian and Cenomanian in France." Nat. Science, vol. xiii., pp. 193-201.

Jukes-Browne, A. J.—"Les Limites du Cénomanien." Réponse à M. Gustave F. Dollfus. La Feuille des Jeunes Naturalistes, Ser. III., Aug., 1898.

Jukes-Browne, A. J. and J. Milne.—"On the Cretaceous Fossils found at Moreseat, Aberdeenshire." Geol. Mag., Dec. IV., vol. v., pp. 21-32.

Lamplugh, G. W.—"Some Open Questions in East Yorkshire Geology." Trans. Hull Geol. Soc., vol. iv., pp. 24-36.

Newton, E. T.—"Palæolithic Man." Presidential Address to the Geologists' Association. Proc. Geol. Assoc., vol. xv., p. 246, 1898.

Newton, E. T. and J. J. H. Teall.—"Additional Notes on Rocks and Fossils from Franz Josef Land." Quart. Journ. Geol. Soc., vol., liv p. 646, 1898.

Reid, C.—"The Eocene Deposits of Devon." Quart. Journ. Geol. Soc., vol. liv., 1898, pp. 234-238.

Reid, C.—"On *Limnocarpus*, a new Genus of Fossil Plants from the Tertiary Deposits of Hampshire." Journ. Linn. Soc. Botany, vol. xxxiii., pp. 464-466.

Reid, C.—"Further Contributions to the Geological History of the British Flora." Annals of Botany, vol. xii., pp. 244 250.

Sharman, G., and E. T. Newton.—"Notes on some Additional Fossils collected at Seymour Island, Graham's Land, by Dr. Donald and Capt. Larsen." Proc. Roy. Soc. Edinburgh, vol. xxii., p. 58, 1898.

Strahan, A.—"On the Revision of South Wales and Monmouthshire by the Geological Survey." (Brit. Assoc., Bristol, 1898.) Geol. Mag., Dec IV., vol. v., pp. 488-493.

STRANGWAYS, C. FOX—"Sections along the Lancashire, Derbyshire, and East Coast Railway, between Lincoln and Chesterfield." Quart. Journ. Geol. Soc., vol. liv., pp. 157-167.

TEALL, J. J. H.—"A Phosphatized Trachyte from Clipperton Atoll, Northern Pacific." Quart. Journ. Geol. Soc., vol. liv., pp. 230-232.

USSHER, W. A. E.—"The Geological Structure of Devon." Trans. Plymouth Inst.

WEDD, C. B.—"On the Corallian Rocks of Upware (Cambs)." Quart. Journ. Geol. Soc., vol. liv., pp. 601-619.

WOODWARD, H. B.—"On Arborescent Carboniferous Limestone from near Bristol." (Brit. Assoc., Bristol, 1898.) Geol. Mag., Dec. IV., vol. vi., pp. 77, 78 (1899).

INDEX.

Aberdeenshire, 4, 5, 20, 172
Achnasheen, 6, 11
Acton Turville, 190
Aegerine-granulites, 24, 25, 195
Allen, H. A., 1
Amia, 201
Analyses of Rocks, 42, 43, 88, 127, 190, 192, 196-200
Andesite, 72, 111
Archidesmus loganensis, 65
Ardrishaig, 38, 51
Arenig Rocks, Ireland, 56-58
Argyllshire, 4, 5, 38, 152, 169, 186
Arklow, 57, 58
Arran, Isle of, 5, 20, 52, 53, 93, 131, 133, 150, 168, 185
Ashbourne, 161
Ateleaspis tessellata, 65
Augen-gneiss, 9
Avoch, 69
Awe, Bridge of, 129-131
Ayrshire, 64-66

Badenoch, 5, 35, 36
Bagshot Beds, 144, 145
Bala Limestone, Ireland, 58, 59
Balquhidder, 37, 38
Banff, 4
Barrow, G., 2, 5, 20-23, 25-27, 88, 120-122, 135-137, 164, 211
Basalt, 105, 146
Bassey Mine Ironstone, 123
Beauly, 5, 17-18, 70, 71, 174
Bell, A., 204
Ben Cruachan, 5, 39, 76-78, 81-93
Ben Ledi, 37
Bennett, F. J., 3, 140, 187, 188, 207, 208
Bennie, J., 158
Ben Nevis, 44-47, 171
Berkshire, 3
Black Band Series, 123
Black Isle, 68-70, 174, 176
Blackmore, Dr. H. P., 189
Blake, J. H., 3, 139, 158, 159, 207, 210, 211
Boring, Isle of Man, 167, 168; Oxford, 139
Braemar, 5, 20-25, 31-33, 172,195
Braemore, 18, 19, 66-68, 178
Brander, Pass of, 76, 82, 92
Bray, 57
Brecknock, 111, 164
Brick-earth, 3
Bridgend, 138, 201
Brinkworth, 189
Bristol Coal-field, 193
British Guiana, Rocks from, 196
Brown, H. T., 135
Buckinghamshire, 3
Building Stone, 69, 71, 73, 136
Burslem, 122, 123

Cadell, H. M., 54
Cairngorm (Mineral), 28
Cairngorm, 22, 23, 25, 27, 172
Caithness, 4, 6, 18, 66-68, 178
Calcareous Tufas, 158
Cambrian, 53, 197
Cameron, A. C. G , 2, 3, 208
Cantrill, T. C., 4, 94, 111-114, 117, 119, 134-135, 138, 139, 164-167, 211
Carbonia, 116, 122
Carboniferous, 76, 103, 191, 193
Carboniferous Outliers, New, 76, 117, 129; Volcanic Rocks, Somerset, 104
Carboniferous Limestone, 111, 191
Carrick-on-Suir, 61, 62
Carstone, 141, 142
Cavan, 63, 64
Chalk Downs, 140
Chalk Rock, 139
Champernowne, A., 96
Chapel Chorlton, 136
Charnwood Hills, 159
Chipping Sodbury, 191, 192
Clark, R., 6, 56-62
Clay-with-flints, 184
Close, Rev. M. H., 183
Clough, C. T., 4, 6, 53, 54, 155, 200
Coal-fields, 111, 120, 193
Coal-measures, 114, 122, 131, 132, 193
Codrington, T., 185
Colenutt, G. W., 201
Colour-banding, 23
Contact-metamorphism, 82
Cordierite Rocks, 86
Corries, 183
Cork, 6, 60
Cornwall, 3, 95, 97, 183
Corundum, 87, 195
Cotham Stone, 191, 194
Cotteswold Hills, 190
Courtown, 57-59
Cowbridge, 94, 119, 134, 138, 167
Cranborne Chase, 140
Cretaceous, 139, 187, 188
Cretaceous nomenclature, 143
Cribarth Fold, 117
Crick, G. C., 204
Cromarty, 4, 68, 69, 175
Cuillin Hills, 5, 146, 148, 179
Culm-measures, 95, 96, 103
Cunningham-Craig, E. H., 5, 20, 23-25, 27-34, 37, 38, 172, 173, 195
Cuttings, new Railway, 187

Dalradian Rocks, 20
Dartmoor, 95
David, J., 201
Davis, T., 188
Deeley, R. M., 189
Dee, River, Scotland, 20, 21, 23, 25 27, 31, 32, 172
De Rance, C. E., 1, 2, 120

Derbyshire, 2, 120, 135
Devon, 3, 94-96, 103, 104
Diorites, 25, 81
Director General, 19, 50, 51, 54, 59, 66-68, 74-76, 104-111, 137, 138, 151, 154, 155, 211
Dittmar, C., 89
Dolomite, 192, 196-200
Dolomitic Conglomerate, 134
Donald, J., 205
Dorset, 3, 5, 139, 145, 184
Dove, River, 159
Downtonian, 64
Drift, 156; Marine Shells in, 163, 164; Diversion of Drainage by, 166, 173
Duncan, Mr., 131
Dungarvan, 58
Durness Limestone, 53

Easdale, 49, 50, 72, 75
Edinburgh, City of, 131
Egan, F. W., 6, 55-60, 210
England and Wales, Field-work in, 1
Enniscorthy, 57
Eoliths, 189
Epidiorites, 91
Erratics, Scotch, in Midlands, 163; Lake District, in Midlands, 163; Welsh, in Midlands, 163
Eskers, 169
Etruria Marls, 123, 125

Falmouth, 97-100
Fannich Forest, 4, 11-15, 174, 176
Farewell Rock, 114
Faults, 116, 128
Fenton Park Clay-pits, 127
Fire Bricks, 113
Fishes, Fossil, 65, 71
Foliated Igneous Rocks, 9
Fortrose, 68, 69, 177
Fort William, 40
Fossils figured, 204
Fox-Strangways, C. *See* Strangways
Fox, H., 101
Franz-Josef Land, 203

Gabbro, 148
Galtymore, 61
Geikie, Sir A. *See* Director General
Gerrans Bay, 97, 100, 183
Gibson, W., 2, 4, 111, 114-116, 118-120, 122-129, 135, 162, 163, 165, 166, 208
Glacial, 156
Glamorgan, 112, 133, 138, 167
Glas Eilean, 75, 76
Glen Albyn, 44
Glenelg, 4, 6, 7
Glen Etive, 5, 20, 38, 39, 76, 78, 81, 82, 92, 169
Glen Loy, 40, 42-44
Glenpatrick, 62, 63
Glen Roy, 45, 171
Gneiss, 6, 18, 22, 35, 40
Goodchild, J. G., 211
Grampian Hills, 25
Granite, 25, 27, 36, 39, 43, 76-78, 81-93, 102, 150
Grant-Wilson, J. S., 5, 18, 21, 40-49, 152, 153, 155, 156, 170, 171, 196
Graptolites, 57, 58, 60, 202
Gravel, 3
Great Glen, 17, 18, 40, 49
Great Western Railway, 187
Green, Prof. A. H., 121
Greensand, Upper, 139, 140, 143; Lower, 141
Gregory, W., 190
Gunn, W., 5, 11, 13, 16, 20, 52, 53, 93, 146, 150-152, 168, 169, 185, 186, 210, 211

Hampshire, 3, 144
Hanley, 123
Harker, A., 5, 53, 54, 137, 146-150, 154 162, 163, 179-182, 198, 211
Harrison, Professor J. B., 196
Hatch, Dr. F. H., 59
Hawkins, C. E., 3, 144, 208
"Head," 184
Helford River, 97, 100, 183
Hill, J. B., 3-5, 38, 76, 96-103, 183, 184
Hind, Dr. W., 205, 206
Hinde, Dr. G. J., 65, 66, 204, 206
Hinxman, L. W., 3, 5, 18, 20, 27, 34-36, 68, 70, 71, 139, 140, 145, 173, 174, 184
Holmes, T. V., 210
Horne, J., 4, 6, 11-17, 68-70, 174, 176, 177
Hornfels-alteration, 22
Hutton, James, 151

Igneous Rocks, 6-52, 59, 63, 68, 72, 75-93, 95, 102, 104, 146, 150, 152, 195
Inchbae Rock 9
Inliers, Cretaceous, 140
Inverness-shire, 6, 17, 35, 173
Ireland, Field-work in, 5, 55, 56, 60, 182, 186
Iron-ore, N. Staffordshire, 127; Cotteswold Hills, 190
Islay, 75
Isle of Man, 167

Jackson-Harmsworth Expedition, 196, 203
Jamieson, T. F., 171
Jones, Prof. T. R., 126, 205, 206
Judd, Prof. J. W., 130
Jukes-Browne, A. J., 143, 144, 208, 210, 211
Jura, Isle of, 5, 20, 50-52, 75, 172
Jurassic, 138, 188-190, 194

Kames, 169
Keele Sandstones, 123, 126
Keeper Hill, 60, 61
Keeping, W., 142
Kellaways Beds, 189
Kerrera, 49, 71, 73
Kettle-moraine, 181
Kidston, R., 72, 124, 129, 131, 206
Kilkenny, 6, 60
Kilmelfort, 49, 72, 186
Kilroe, J. R., 6, 60-63, 210
Kiltarlity, 4, 17, 70
Kinahan, G. H., 63
Kirkby, J. W., 132, 206
Kitchin, Dr. F. L., 1
Koettlitz, Dr. R., 203

Kynaston, H., 5, 20, 38, 39, 76-83, 91-93, 130, 131, 169, 170, 196

Lacroix, A., 77
Lake District Boulders in Midlands, 163
"Lake Orcadie," 67, 68, 70
Lamplugh, G. W., 2, 120, 135, 136, 141-143, 159-162, 167, 168, 207, 210, 211
Lamprophyre, 48
Lanarkshire, 4, 64-66
Landscape Marble, 191, 194
Lapworth, Prof. C., 57, 203
Laurie, Dr. M., 65, 206
Lead-veins, 113
Leek, 164
Leicestershire, 2, 120, 132, 135
Lesmahagow, 65
Lewisian gneiss, 7
Lias, 138, 191
Limerick, 6, 60
Littoral Lias, 138
"*Lit par Lit*" injection, 85
Loch Awe, 5, 20, 38, 39, 76, 82, 169
,, Broom, 11
,, Creran, 49
,, Eil, 5, 18, 20, 40, 152, 155, 156, 170, 171
,, Etive, 75, 79, 82, 169
,, Fannich, 4, 6, 11-17, 177
,, Garve, 6, 10, 11, 71, 186
,, Katrine, 37, 38, 172
,, Leven, 44-46
,, Linnhe, 20, 40, 41
,, Luichart, 4, 6-11, 15-18, 71, 174, 186
,, Maree, 14
,, Ness, 17
Lochy River, 44
London District, 2
Longton, 122, 123
Lorne, 71, 76, 129, 153
Lowestoft, 145

Macadam, Prof. I., 131
Macconochie A., 4, 53, 54, 205
Macculloch, Dr. J., 76
McHenry, A., 6, 55-60, 210
Madeley, 162
Maenporth, 100
Maiden Newton, 3 139, 145
Maps published in 1898, 207
Market Drayton, 162
Meath, 63
"Melange" Junction, 27
Melbourne Rock, 139
Memoirs published in 1898, 209
Mendip Hills, 105, 110
Metamorphism, Contact, 82
Michel-Levy, A., 85
Middle Hope, 105-107
Middlesex, 2, 3
Miller, Hugh, sen., 17, 68
——— H. jun., 68
Millstone Grit, 113, 121
Mitcheson, G., 128
Moffat, 4
Moine-Schists, 7-13, 17-19 21
Monadhliath Mountains, 5 20, 35
Moray Firth, 68, 70
Morgan, Prof. C. Lloyd, 104
Morosewicz, Dr., 91
Morton, G. H., 208
Morven Hills, 18, 19, 66-68, 178
Mundesley, 194
Muscovite-biotite-gneiss, 8-10
Mylor Series, 98

Nathorst, Dr. A. G., 204
Neath, Vale of, 115, 117, 164-166
Newbury, 187
Newcastle-under-Lyme Series, 123, 125
Newton, E. T., 1, 57, 58, 60-62, 108, 196, 199, 201-205, 211
Nolan, J., 182, 183, 186, 187, 210
Non-official Publications, 211
Norfolk, 141, 145, 194
Northamptonshire, 3
North Walsham, 194
Nunatak, 175

Oban, 5, 20, 49, 50, 71-73, 75, 153, 155, 169, 186
Oldhamia, 56, 57
Old Sodbury, 190
Old Red Sandstone, 11, 19, 20, 66, 110, 111
Olenellus-fauna, 54
Oolites, 139, 189
Ord in Sleat, 53
Oxfordshire, 3, 139-141, 158, 159
Oxford, 139, 158
Oxford Clay, 189

Parallel Roads of Glen Roy, 171
Pass of Brander, 76, 82, 92
Palæontological Work, 201
Peach, B. N., 4, 6-11, 15, 18, 54, 55, 58, 64-68, 71, 129, 130, 174-176, 186, 205, 206
———, C. W., 101
Peak Hill Rocks, 96
Peat, 157, 158, 186
Pendennis, 98-100
Pentland Hills, 4, 65
Perceval, S. G., 106
Permian, 132
Permian, so-called, 126, 132
Perthshire, 5, 20, 37, 172
Petrographical Work, 195
Pewsey, Vale of, 187
Pillow-structure in lavas, 106, 108
Pipe-rock, 54
Pleistocene, including Glacial, 156
Plymouth, 103
Pocock, T. I., 4, 6, 14-20, 66-68, 174, 177, 179
Potteries, The, 122, 123
Pollard, Dr. W., 1, 127, 191, 192, 196, 197, 200
Porphyrite, 48, 80, 81
Portlaw, 62, 63
Portscatho Slates, 98
Practical Applications of Geology, 206
Pre-Cambrian, 6

Quartzite, Central Highland, 21

Raasay, 137
Railway-cuttings, New, 187, 188
Raised Beaches, 168, 172, 174, 177, 184, 186

Recent Deposits, 156, 183
Reid, C., 3, 140, 144-146, 156, 158, 163, 164, 194, 201, 205, 208-211
Rhætic, 134, 135, 191-193
Rhodes, J., 1, 196
Rosemarkie, 17, 68, 69
Rosemullion, 99
Ross-shire, 4, 6, 17, 68-71, 174, 186
Rottenstone, 112

Salisbury, 140
Salomon, W., 88, 89
Saltash, 103
Sandringham Sands, 141
Scaddle, 40, 41
Scalpa, 137
Schists, 20, 38, 49
Scotland, Field-work in, 4
Scudder, Dr. S., 65
Selbornian, 143
Severn Tunnel, 189
Seymour, H. J., 1, 6, 60, 63, 64, 195
Sharman, G., 1, 211
Shepton Mallet, 110
Silurian, 56; Fishes, 65; Eurypterids, 65, 66
Skye, 5, 53, 137, 146, 179
Slane, 631
Slates, 49-52, 61, 62, 95
Slievenaman, 61, 62
Soils, Chalky, 188
Soar, River, 159
Sollas, Prof. W. J., 1, 6, 104, 134
Somerset Volcanic Rocks, 104
Southampton, 3
South Wales, 94, 111, 133, 138, 164, 184
South Wales Coalfield, 4, 111
Snettisham Beds, 141
Spean River, 44, 45
Specific Gravity of Rocks, 197
Spey, 20
Sphero-siderite, 127
Staffordshire, 2, 5, 120, 132, 135, 159
Stephens, F. J., 101
St. Mawes, 98-100
Stoke-on-Trent, 123, 162
Strahan, A., 4, 104-111, 114-119, 136, 158, 164-167, 191, 208, 210, 211
Strangways, C. Fox-, 2, 120, 132, 133, 135, 159, 210, 212
Strathspey 18, 34-36, 173
Strath in Skye, 53-55
Strathyre, 5, 37, 38
Sutherland, 6
Swallow-holes, 190
Swansea, Vale of, 115, 164-167
Symes, R. G., 5, 20, 49, 50, 71-75, 153-155, 169, 186

Tait, D., 65, 72, 76, 129, 132, 205
Tarbert, 51, 52
Tarn, Moraine-dammed, 183
Tavistock, 95, 103
Tawe, Vale of, 94, 111, 113, 117, 164
Teall, J. J. H., 13, 14, 24, 25, 28, 30-32, 36-38, 40-48, 77, 79, 80, 83-92, 96, 106, 110, 111, 127, 153, 156, 195, 196, 200, 203, 212
Tertiaries, 144
Thames Basin, 2
Tiddeman, R. H., 4, 111-114, 134, 135, 138, 139, 164-167, 201
Tipperary, 6, 60
Todd, J., 167, 168
Torridon Sandstone, 137
Traquair, Dr. R. H., 65, 72, 132, 206
Trent, River, 159
Trias, 133, 192
Trossachs, 5, 37, 38
Tufas, 158

Uphill, 105
Usher, W. A. E., 3, 95, 103, 104, 208, 210, 212
Uttoxeter, 159-161

Valleys, Dry Chalk, 140
"Variegated Slates," 98
Veryan Beds, 97, 98
Vogelsang, C., 89
Volcanic Rocks, 59, 63, 68, 72, 75, 93, 95, 104, 146, 152

Wales, South, 94, 111, 133, 138, 164, 184
Wallace, Mr., 70
Ward, J., 123
Waterford, 6, 60
Waterstones, 135, 136
Water-supply, 70, 190
Watts, Prof. W. W., 1, 210
Weaver Hills, 160
Wedd, C. B., 1, 2, 120, 126, 129, 135, 136, 162-164, 212
Well at North Walsham, 145
Welsh Erratics in Midlands, 163
Weston-super-Mare, 105, 106
Wexford, 6, 55-60, 63, 182
Whidborne, Rev. G. F., 205
Whitaker, W., 3, 144, 208, 210
Wicklow, 6, 55-60, 63, 182, 186
Wilkinson, S. B., 3, 5, 20, 50-52, 75, 172
Williams, G., 87
Williamson, Prof. W. C., 131
Wilson, J. S. Grant. *See* Grant-Wilson
Wiltshire, 3
Winwood, Rev. H. H., 192
Woodward, Dr. H., 205, 206
——— H. B., 2, 187-194, 212
Wootton Bassett, 189
Wrington Warren, 105, 110
Wünsch, E. A., 131

Yoredale Series, 120
Ystradgynlais, 114

Zanclodon, 202
Zoisite, 8, 13, 14, 16
Zoze Point, 97

INDEX
to the
GEOLOGICAL MAP OF ENGLAND AND WALES
Published on the Scale of One Inch to a Mile
OLD SERIES

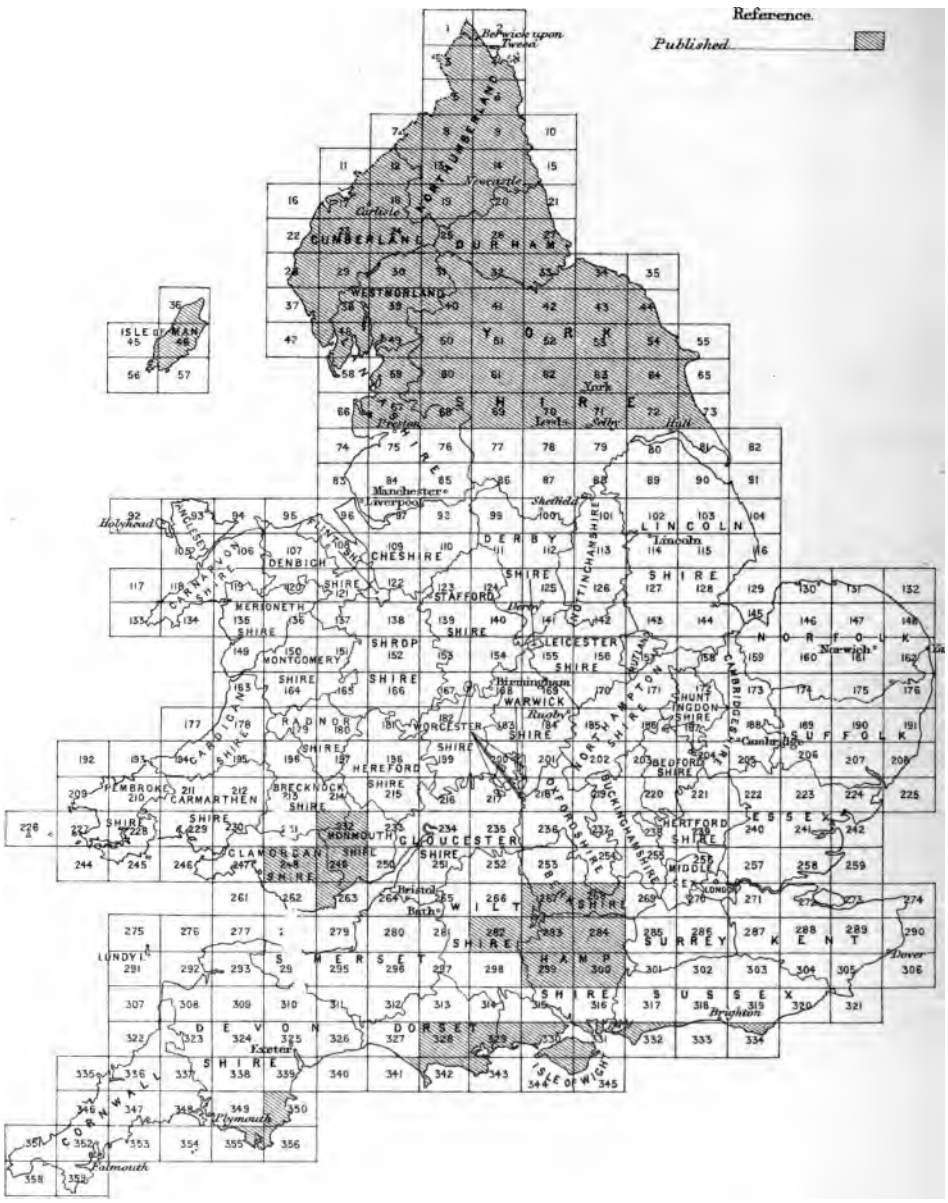
INDEX

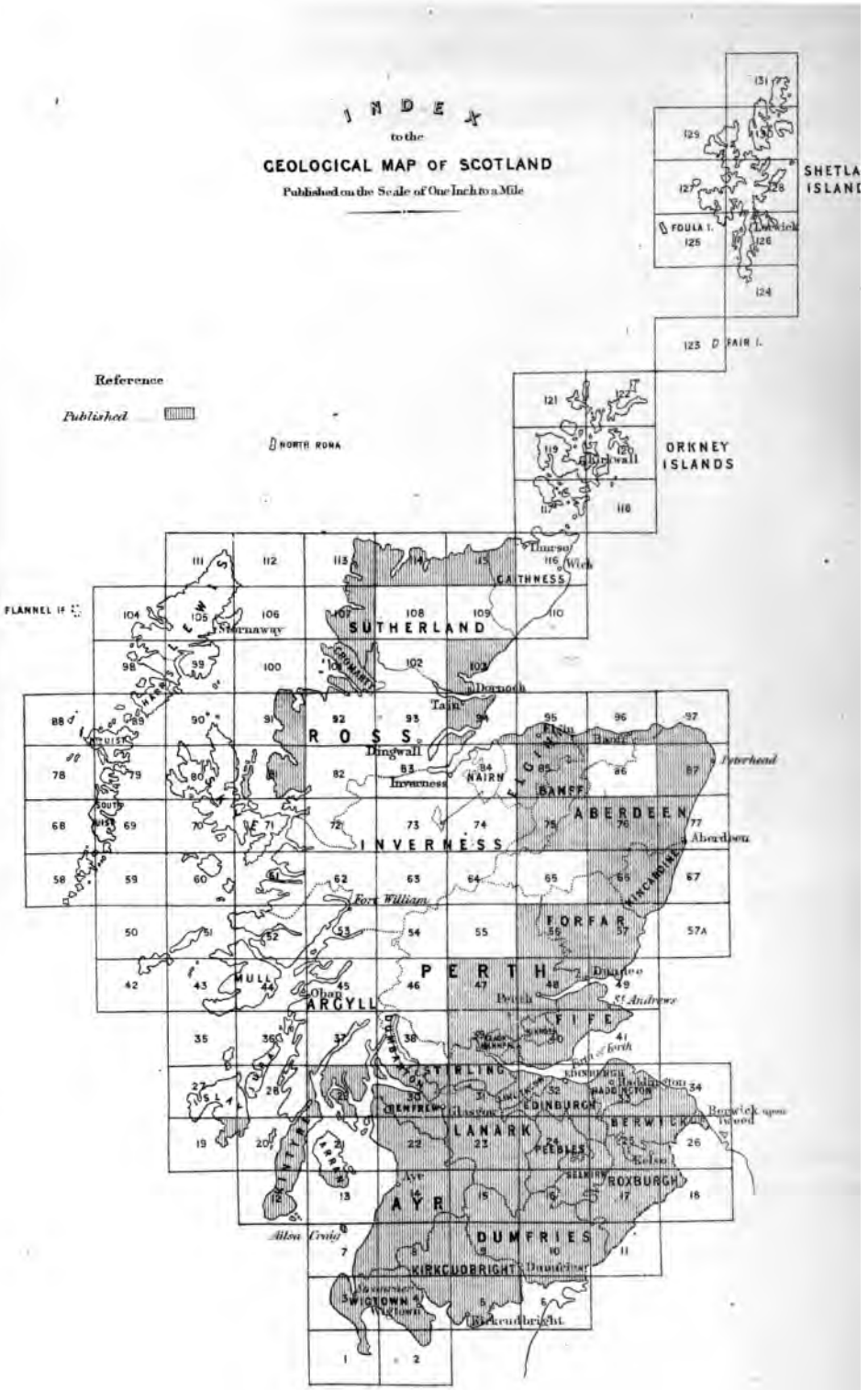
to the

GEOLOGICAL MAP OF ENGLAND AND WALES

Published on the Scale of One Inch to a Mile

NEW SERIES



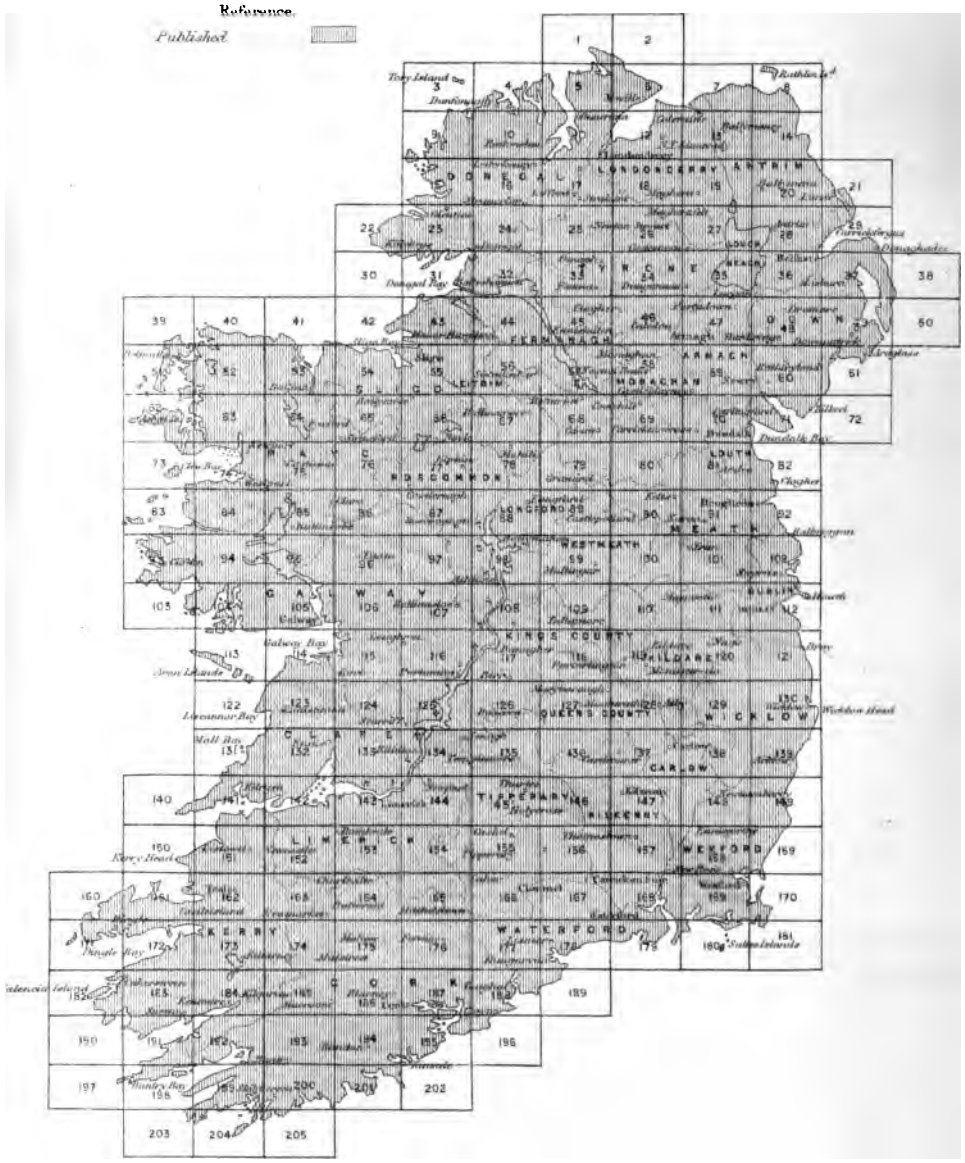

INDEX
to the
GEOLOGICAL MAP OF SCOTLAND
Published on the Scale of One Inch to a Mile
Reference
Published
SHETLAND ISLANDS
FOULA I.
FAIR I.
NORTH RONA
ORKNEY ISLANDS
Kirkwall
Thurso
Wick
CAITHNESS
FLANNEL IS.
Stornaway
SUTHERLAND
CROMARTY
Tain
Dornoch
Dingwall
ROSS
Elgin
Banff
Peterhead
Inverness
NAIRN
BANFF
ABERDEEN
INVERNESS
Aberdeen
Fort William
KINCARDINE
FORFAR
PERTH
Dundee
Perth
St Andrews
MULL
Oban
ARGYLL
FIFE
Forth
STIRLING
Edinburgh
Haddington
RENFREW
Glasgow
EDINBURGH
BERWICK
Berwick upon Tweed
LANARK
PEEBLES
Selkirk
ROXBURGH
AYR
Ayr
Ailsa Craig
DUMFRIES
KIRKCUDBRIGHT
Dumfries
WIGTOWN
Wigtown
Kirkcudbright

INDEX

to the

GEOLOGICAL MAP OF IRELAND

Published on the Scale of One Inch to a Mile



SHEET MEMOIRS OF THE GEOLOGICAL SURVEY—continued.

- NORWICH. By H. B. Woodward. 7s.
- ATTLEBOROUGH. By F. J. Bennett. 1s. 6d.
- E. DEREHAM. By J. H. Blake. 1s. 6d.
- YARMOUTH and LOWESTOFT. By J. H. Blake. 2s.
- CROMER. By C. Reid. 6s.
- FAKENHAM, WELLS, &c. By H. B. Woodward. 2s.
- BORDERS OF THE WASH. By W. Whitaker and A. J. Jukes-Browne. 3s.
- S.W. LINCOLNSHIRE, &c. By A. J. Jukes-Browne and W. H. Dalton. 4s.
- NOTTINGHAM. By W. T. Aveline. (2nd Ed.) 1s.
- RHYL, ABERGELE, and COLWYN. By A. Strahan. (Notes by R. H. Tiddeman.) 1s. 6d.
- FLINT, MOLD, and RUTHIN. By A. Strahan (Parts by C. E. De Rance). 4s. 6d.; *Supplement*, 2d.
- PRESCOT, LANCASHIRE. By E. Hull. (3rd Ed. With additions by A. Strahan.) 3s.
- ALTRINCHAM, CHESHIRE. By E. Hull. 8d. (O.P.)
- CHESTER. By A. Strahan. 2s.
- STOCKPORT, MACCLESFIELD, CONGLETON, & LEEK. By E. Hull and A. H. Green. 4s.
- PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. Aveline. (2nd Ed.) 6d.
- PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. Aveline. 1s.
- LINCOLN. By W. A. E. Ussher, A. J. Jukes-Browne, and A. Strahan. 3s.
- EAST LINCOLNSHIRE. By A. J. Jukes-Browne. 3s. 6d.
- N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. Ussher [and Others]. 1s.
- WAKEFIELD and PONTEFRACT. By A. H. Green. 6d.
- BARNSLEY. By A. H. Green. 9d.
- OLDHAM. By E. Hull. 2s.
- PART of the YORKSHIRE COAL-FIELD. By A. H. Green, J. R. Dakyns and J. C. Ward. 1s.
- DEWSBURY, &c. By A. H. Green, J. R. Dakyns, J. C. Ward, and R. Russell. 6d.
- BOLTON, LANCASHIRE. By E. Hull. 2s.
- WIGAN. By Edward Hull. (2nd Ed.) 1s. (O.P.)
- The COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. De Rance. 3d. (O.P.)
- SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. De Rance. 6d.
- The COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. De Rance. 6d.
- SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. Aveline. 6d.
- BRADFORD and SKIPTON. By J. R. Dakyns, C. Fox-Strangways, R. Russell, and W. H. Dalton. 6d.
- NORTH and EAST of HARROGATE. By C. Fox-Strangways. 6d.
- The COUNTRY between YORK and MALTON. By C. Fox-Strangways. 1s. 6d.
- N. and E. of LEEDS, and near TADCASTER. By W. T. Aveline, A. H. Green (and others). (O.P.)
- COUNTRY between YORK & HULL. By J. R. Dakyns, C. Fox-Strangways, and A. G. Cameron. 1s.
- DRIFFIELD. By J. R. Dakyns and C. Fox-Strangways. 9d.
- BRIDLINGTON BAY. By J. R. Dakyns and C. Fox-Strangways. 1s.
- SCARBOROUGH and FLAMBOROUGH HEAD. By C. Fox-Strangways. 1s.
- WHITBY and SCARBOROUGH. By C. Fox-Strangways and G. Barrow. 1s. 6d.
- NEW MALTON, PICKERING, and HELMSLEY. By C. Fox-Strangways. 1s.
- ESKDALE, ROSEDALE, &c. By C. Fox-Strangways, C. Reid, and G. Barrow. 1s. 6d.
- NORTHALLERTON and THIRSK. By C. Fox-Strangways, A. G. Cameron, and G. Barrow. 1s. 6d.
- INGLEBOROUGH. By J. R. Dakyns, R. H. Tiddeman, W. Gunn, and A. Strahan. 2s.
- MALLERSTANG. By J. R. Dakyns, R. H. Tiddeman (and others). 2s. 6d.
- KIRKBY LONSDALE and KENDAL. By W. T. Aveline, T. Mc K. Hughes, and R. H. Tiddeman. 2s.
- KENDAL. By W. T. Aveline and T. Mc K. Hughes. 2nd Ed. by A. Strahan. 2s.
- NORTHERN PART of the ENGLISH LAKE DISTRICT. By J. C. Ward. 9s.
- APPLEBY, ULLSWATER, and HAWESWATER. By J. R. Dakyns, R. H. Tiddeman, and J. G. Goodchild. 1s. 6d.
- NORTH CLEVELAND. By G. Barrow. 1s. 6d.
- CARLISLE. By T. V. Holmes. 1s. 3d.
- OTTERBURN and ELSDON. By Hugh Miller. 2s. 6d.
- CHEVIOT HILLS. By C. T. Clough. 1s. 6d.
- PLASHETTS and KIELDER. By C. T. Clough. 1s.
- WOOLER and COLDSTREAM. By W. Gunn and C. T. Clough. 1s. 6d.
- NORHAM and TWEEDMOUTH. By W. Gunn. 6d.
- COAST south of BERWICK-ON-TWEED. By W. Gunn. 9d.

(Series) BOURNEMOUTH. By C. Reid. 4d.
BOGNOR. By C. Reid. 6d.
EASTBOURNE. By C. Reid. 6d.

COAL-FIELDS AND OTHER MINERAL DISTRICTS.—Scale, six inches to a mile.

Coal-fields and other mineral districts of the N. of England are in part published on a scale of six inches to a mile, 1s. each. M.S. Coloured Copies of other six-inch maps, not intended for publication, are deposited for reference in Geological Survey Office, 28, Jermyn Street, London.

THE IRON ORES OF GREAT BRITAIN.

The North and North Midland Counties of England (*Out of print*). Part II. South Staffordshire. Price 1s. Part III. South Wales. Price 1s. 3d. Part IV. The Shropshire Coal-field and North Staffordshire. 1s. 3d.